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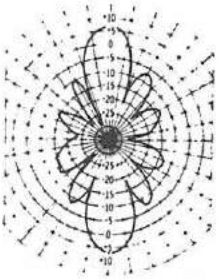

THE PRACTICAL HANDBOOK OF AMATEUR RADIO FM & REPEATERS

by
Bill Pasternak, WA6ITF with Mike Morris, WA6ILQ, Technical Advisor.

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This book is dedicated to all the men and women of the amateur community who have helped develop the amateur relay technology of yesterday, today, and the future.

Special thanks to Arthur Gentry, W6MEP, Burt Weiner, K6OQK, and

To L.K.S., who taught me I could do anything I put my mind to; to my wife Sharon who has stuck with me through a lot of hard times and gave me the will to keep going and to Roy Neal, K6DUE, who was my inspiration.

Preface

Upon reading the completed manuscript of this book, one of its technical contributors stated, "Maybe you should call it 'Everything You Always Wanted to Know About Repeaters but Didn't Know Whom to Ask!" I looked up at him and said, "If that's right, then the past two years really mean something."

I've never attempted writing a book before. Magazine articles, educational film scripts—yes; a book—no. However, for many years I have wanted to do just that—write a volume dedicated to an aspect of amateur radio that I know and love. I thought about it, but for years kept it on the back burner. Then, a little over two years ago I received a rather unexpected letter asking if I would be interested in taking on such a project.

At the outset, I set down some guidelines for both myself and those who might contribute to the book. True we would be doing a technical book, but it had to be more than just "another repeater book." First, it had to be kept simple so that virtually any amateur who picked it up could read it and, for the most part, understand it. Having been around amateur radio since 1958 as WA2HVK, I have learned one truism: Not every amateur is a technical expert, though almost all amateurs have a desire to learn as much as they can about the hobby itself. In writing this book, I have kept this in mind, and I think you will enjoy the difference.

Secondly, it had to be more than the average how-to-do-it book. Rather, it had to be filled with concepts and ideas that most amateurs could associate with. Here, again, I think we have succeeded. We begin with the "historical aspects," enter the "system planning phase," "construct our relay entity," and finally, we guide the repeater's day to day operation. It's a concept used before, true, but one I have never seen in a book on this subject. Call it a change from tradition, if you will. Nonetheless, I hope you enjoy it this way. Finally, this is your book as much as it is mine. If not for you, the people of today's "amateur repeater community," this book could never have been written. It is for that reason that I dedicate it to all of you. You made it happen.

Bill Pasternak, WA6ITF

Approximately six months ago, Bill Pasternak came to me and asked that I do "a couple of chapters" on basic repeaters, remote bases, etc., for his new book. Well, like Topsy, things have a way of growing. Here you see our literary efforts. After you have finished reading our book and building your system, we would appreciate a letter describing your efforts. We ask this because this is not the last book of this kind; another one will be published eventually, and some of *your* ideas might end up in it.

Lastly, in this book, you will find both theory and practice; that is, actual circuits. The circuits shown are the favorites of the contributors and the authors—but that is not to say that others are not better. Every person has his favorite way of doing things. A Celtic word, *lai*, means a verse, hymn, or poem, and was used by Rudyard Kipling as he referred to an Indian chant: "There are nine and sixty ways of constructing tribal lays, and every single one of them is right."

Mike Morris, WA6ILQ

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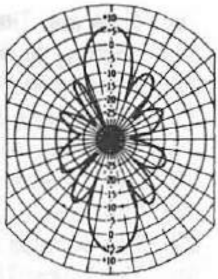

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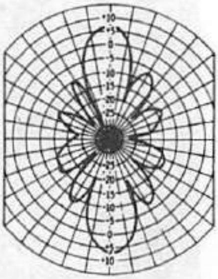
Chapter 1

Once Upon A California Hilltop



"There are two kinds of wind. One is a cold one which blows from the North and the other a warm one which is called the Western Wind. We each must choose the one we want, and follow it wherever it may lead."

The above words were those of a close friend of mine, spoken one evening long ago. While the statement had nothing to do with Amateur Radio at the time it was said, little did I know the effect it would have upon me in years to come. She was leaving to follow the North Wind and, as I would find out later, it would be an adventure to end all adventures. I, on the other hand, would travel my own road in search of the elusive Western Wind; a wind that would eventually lure me from the concrete canyons of New York City to the lush green mountains and sandy beaches of Southern California. As I digress in thought, I realize how apropos the above statement has been in our two lives, and moreover, how it has led to this book.

In 1969, some time after repeater operation began with rigs such as those shown in Figs. 1-1 through 1-3, TAB published the first book devoted to this subject. It was written by Ken Sessions, K6MVH, and in it's day it was the FM operators bible. The basic precepts and theory therein is as true today as it was in 1969. However, while basic theory holds true, technology advances. Nowhere is it more true than in the electronics industry. What was thought of as "impossible" less than ten years ago is today considered commonplace. The hand calculator, the home video-cassette recorder, and the home microprocessor. These are but three examples of how tomorrow has become today. The same is true of all phases of communication, Amateur Radio included. Where the FM operator of 1969 had only surplus commercial radios to operate with, today's FMer not only has a radio that will fit in the palm of his hand, but one that will cover an entire band without the need to purchase a single crystal. The "boat anchors" of the past required hours of modification to get into operation. Today's amateur equipment is designed to operate at once. Some of it is so sophisticated that not only will it operate FM, but all modes.

MY FIRST REPEATER EXPERIENCE

Time has marched on, and with it technological advancement. However, I can still remember my first experience with "relay device," or "repeater." It happened in 1967. It was my second trip to Southern California, a combination business and pleasure trip, and I had brought with

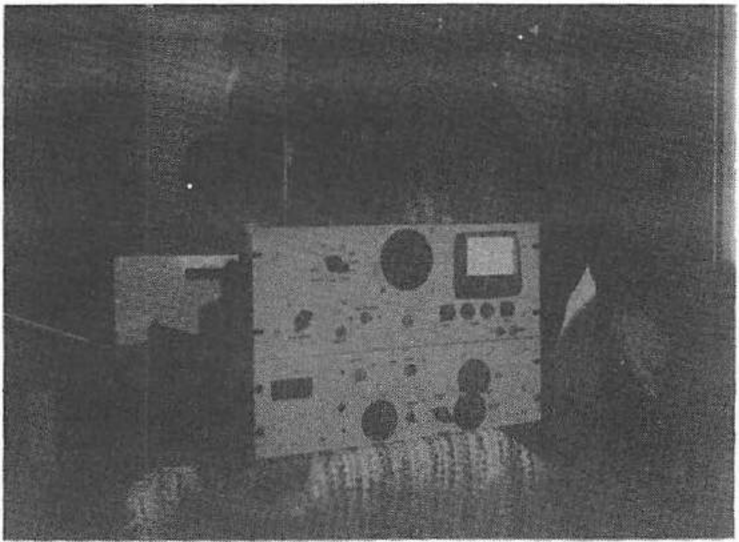


Fig. 1-1. Front view of the original K6MYK repeater receiver.

me my even then venerable Heathkit Twoer AM Transceiver. Stringing my dipole across the hotel room, and securing it with masking tape I proceeded to apply 110V to the beastie. I expected the normal Twoer hiss to greet my ears. Instead, I heard what must have been the strongest signal in the world. It was a funny signal in that each time someone would stop talking there was this beeping sound, and, though many people seemed to be in the QSO, all were the same signal strength. What was this weird signal anyhow? A number of the people talking kept referring to something called "the machine" and the "MYK Box." I pondered this for a while, and then realized that there was a place to find the answer. I jumped into my rented LTD and made a bee-line to Henry Radio in West Los Angeles, cornered one of the sales people and asked kind of sheepishly what an "MYK Machine" was.

My question didn't faze him one bit. He explained briefly what a repeater was, and offered to sell me a crystal so as to use it. "Why not?" A bit later that afternoon, WA2HVK/6 was welcomed into the world of Amateur relay communication by the users of the K6MYK repeater on Mt. Lee, Hollywood, California. I had no way of knowing then where this experience would lead me—that within a few short years, I would be part of the first split-split FM repeater in the nation; that I would be writing about this mode of operation and end up with a column in a national magazine, as a contributing writer to an Amateur Radio film, and as the author of this book.

I am not going to tell you that FM and amateur repeaters were invented in California. The fact is that no one is quite sure who built the nation's very first repeating system. Whenever you research back far enough to think you have found the "one;" someone else comes along with information that takes you back even further. Therefore, I will not try to solve this age old mystery, rather, I will concentrate upon what I know to be fact.

Anyone other than a true neophyte is aware that Major Edwin Armstrong invented frequency modulation. However, many of you probably do not know that it was an amateur who is responsible for what is termed narrow-band FM. NBFM, as it is commonly referred to today, was developed by Jack Babkes, W2GDG. Some of you who have been around this hobby may remember the old Sonar FM exciter/modulator and some early NBFM experiments with the mode on 10 meters. Jack founded Sonar, and through his efforts NBFM became an accepted mode for communication.

Enter repeaters. Many amateurs around the nation take credit for having developed the "first" amateur repeater, and it's an impossible task to say which one is the grandaddy of them all. However, if one judges by longevity and technical system advancement over the years, then you come up with but one callsign, K6MYK. In the late 1950s an Amateur named Arthur Gentry, callsign W6MEP, placed into operation a repeating device atop Mt. Lee, Hollywood, California, designed to extend 2-meter coverage throughout the greater Los Angeles area. To that end, Art had spent many years in developing this system, and it soon became a very popular meeting place for Los Angeles area Amateurs. The original K6MYK repeater was "tailed-carrier" AM, and was the true forerunner of many things to come. Today, K6MYK, under its current WR6ABN callsign, as well as its direct offshoot WA6TDD (now WR6ABE) are still in operation—though both have gone to FM some years ago. Both repeaters have had much written about them over the years, and were sort of the "jumping off point" from which most of what we have nationally has grown. Therefore, if Southern California cannot lay claim to having developed the first practical amateur repeater, they can take title to having developed the repeater concept into a rather exact science, and the Amateurs of that region can take pride in having been the pioneers of it all.

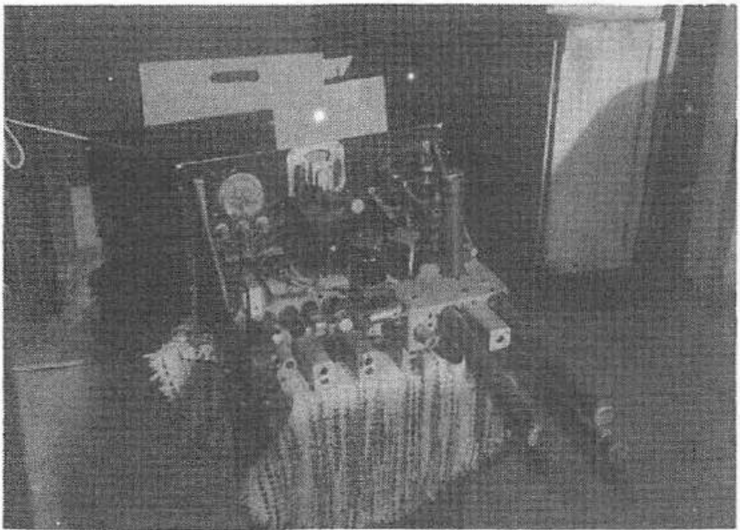


Fig. 1-2, The MYK receiver, developed in the 1950s by W6MEP served for more than 10 years.

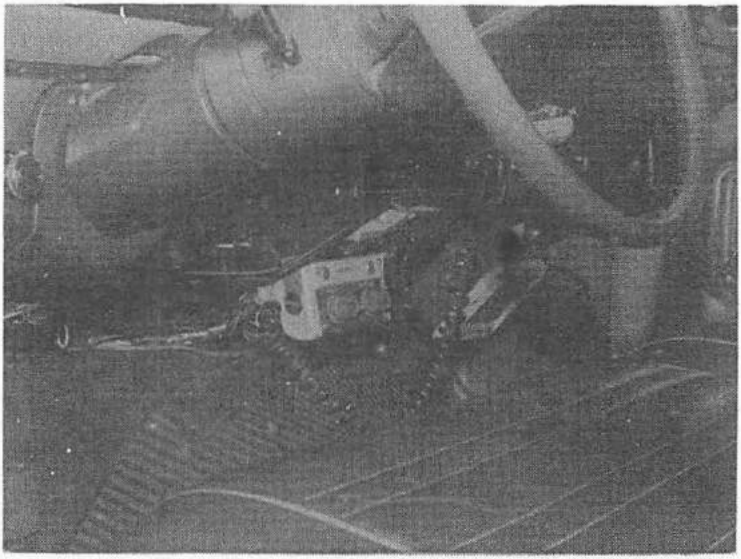


Fig. 1-3. Early mobile installations showed but a control head, microphone, and speaker.

Coming closely on the heels of K6MYK was another repeater whose callsign was W6FNO. FNO differed markedly from MYK in that it was not tailed-carrier AM, but rather used FM as a mode, and its transmitter only operated when a carrier appeared on its receive frequency. As far as I have been able to determine, W6FNO at Radio Ranch, Johnstone Peak, near Pomona, California is among the first true FM repeaters this nation has seen. It also happened to be, in good part, the "brainchild" of Ken Sessions, K6MVH. To prove that something good lasts and lasts, I am happy to report that W6FNO, for a while under WR6ACD, is still with us and going strong.

THE DISCOVERY OF HAM FM

Something interesting happened in the late sixties and early seventies. A nation discovered FM and FM repeaters. That is to say, the nation's amateurs discovered the "Fun Mode" thanks in good part to the efforts of amateur radio publisher Wayne Green, W2NSD. Long before any other major amateur publication was involved in the "FM scene", Wayne's publication, *73 Magazine*, was up to its printing press in reporting on this still new mode within the amateur service. Construction articles, surplus-conversion articles, and direct, positive editorial comment—all helped inform the amateur community of the seemingly limitless possibilities that repeater communication offered. A lot of people must have read what Wayne had to say back then, because soon FM repeaters were beginning to spring up all over the place. See Fig. 1-4.

My first East Coast encounter with an FM repeater was in late 1969, and came in a package called WA2SUR. While the Metro New York area is today loaded with repeaters, one every 15 kHz, in those days there were no "standard channels" and very few systems. If K6MYK brought the repeater concept itself to light, then it was WA2SUR that brought it to popularity in New York. Many have said that WA2SUR was way ahead of its time. In an era when most area repeaters were structured mini-societies, WA2SUR's licensee, George LeDoux, K1TKJ had only two rules: Respect the other guy, and have fun; not necessarily in that order.

Did the "SUR" people have fun? You bet your sweet synthesizer they did. While most repeater groups were holding organizational meetings, WA2SUR people attended parties and other innumerable social events. It only took a user to say the magic word "party," along with a location, to have two or three hundred amateurs show up for a typical "SUR Bash." Think I'm kidding? I was there at many of them. I think it is safe to say that WA2SUR brought more amateurs of that era and area to FM than anything that had come before, and maybe after. Not that WA2SUR was the only New York area repeater of that era, or the first for that matter. Long before SUR was placed into operation, WA2UWC at Greenbrook, New Jersey, and WA2ZYY in Staten Island, to name but two of the earlier achievers appeared. And, entities such as Manhattan's WA2KEC, and Brooklyn's WA2ZWP came hot on their heels. No, "SUR" was far from being alone in it's world, but, because of it's totally liberal attitude, it attracted amateurs by the truckload, and in short order had become the FM "In Spot" in the Metro New York area.

Traveling cross-country in those days did not require a synthesized radio. In fact, my pert Icom IC-2F had but six channel pairs in it. They were 146.94 MHz simplex, plus repeater pairs on 146.13/.73, 146.22/.82, 146.25/.85, 146.28/.88, and the inevitable 146.34/.94. In the trunk a second radio sat—a two-channel RCA LD-150 commercial set converted to

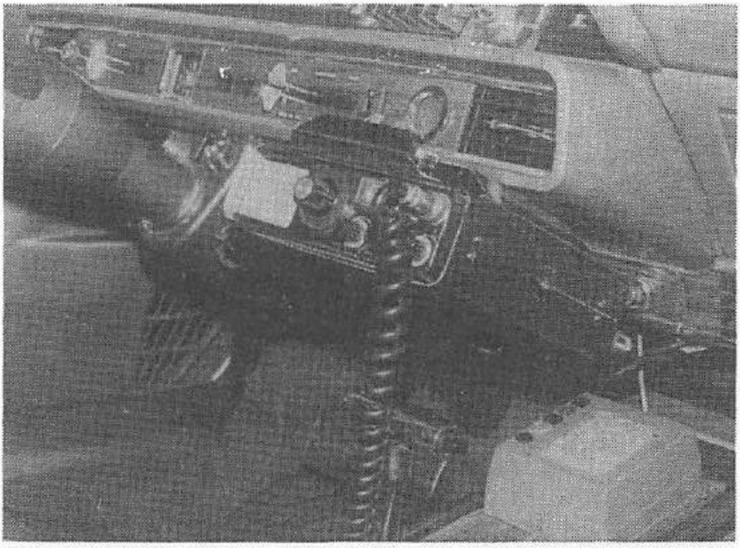


Fig. 1-4. By the early 1970s, one-piece transceivers could be found under the dash of many mobile stations.

Fig. 1-5. Jim Hendershot, WA6VQP, services his 220-MHz repeater.

two meters with 146.52 simplex and the 146.16/.76 repeater pair in it. Even back then, with but these eight channel pairs, I was hardly ever out of radio range of some open repeater as I meandered across the lower portion of the United States. It's hard to remember specific callsigns of systems in given places, but wherever I ventured, there was always a friendly voice emanating from the speaker to give us directions into town or direct us to that area's best eat spot. I can remember the feeling of security that the radio brought as we drove thru a blinding rainstorm between Tulsa and Oklahoma City. I can still picture the goodbye party that members of Albuquerque's WA5JDZ repeater held for us the evening before we started the last leg of our journey to Los Angeles. These were the things that money could not buy; the times that will live within me forever.

When I reached the California border something strange happened. My radio quit working on repeater pairs. Simplex contacts abounded, but not a single repeater could be accessed on the many "standard channels." Actually, there was nothing wrong with my radio, but rather California was still three weeks from implementing channel standardization. So, what had worked so well over 90% of the nation was almost useless for the moment, and it was .94 simplex all the way to the blue Pacific.

Within a few days, we were settled in our San Fernando Valley apartment, and, while awaiting my furniture to arrive, I took the time to set up the Amateur equipment. I had brought everything, including antennas and rotor. After installing the 8-element Cush-Craft on the roof, I connected it to an Ameco CN-144 converter, and that to my HQ-110. Using the six-meter band as a tunable I-F, I began to peruse two meters, and found repeaters everywhere—but not on what we consider to be a standard channel. Then one caught my fancy. It identified under the callsign WA6TDD, and seemed loaded with people 24 hours a day; loaded with people having one heck of a good time. Frankly, it sounded a lot like WA2SUR, and immediately, a thought went through my mind: "I've found a home."

Fig. 1-6. Joe Domke, W2MNN, makes a phone call through the simplex autopatch that he helped develop.

Getting on "TDD" was not as hard as one might think. Along with the HQ-110, I also had toted with me an AMECO TX-62 Transmitter and 621 VFO. Overhearing a QSO in which Chris, WA6HGW, was describing an FM modification for the 621, I made it a point to locate and introduce myself

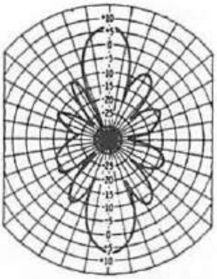
Fig. 1-7. Ray Von Neumann, K6PUW, has been a forerunner in developing circular polarization for Amateur repeaters.

Fig. 1-8. Bob Bloom, W6YUY, of "Ultimate Kicker For Two" fame (Chapter 18), relaxes in his radio room.

to him, and procure the VFO modification. Chris was very helpful, and within a few hours of taking the chassis out of its cabinet, I, too, had become 'a part of the usership of one of this nation's best known amateur repeaters, WA6TDD.

TDD might best be described as "SUR's" big brother. It had been around longer and had twice the usership and ten times the coverage. The latter facilitated by it being atop a mountain known as Mt. Wilson. Otherwise, they were the same, and the many friends that I gained as a result of getting on TDD are still a close part of my life today. TDD has undergone many evolutionary changes over the years, becoming WR6ABE, then WR6AMD, and finally, WA6KOS, which it remains today. Currently, with a usership of over 600, it is probably this nations busiest repeater. While the equipment itself is still the property of another pioneer, Burt Weiner, K6OQK, it has had many licensees, with Dave Ferrone, WA6KOS, its latest. Many visitors to L.A. go out of their way to obtain special crystals necessary to operate on it's rather odd channel pair of 147.435 MHz in and 146.40 MHz out. Why the odd channel pair? This is dictated by it's site. It is located among the many TV and FM broadcast stations that serve the Los Angeles market, and its channels were carefully chosen so as not to interfere with, or be itself interfered with, any other RF generated on the hill. Hence the 1.035 MHz input-to-output separation. An odd split indeed, but one that has had little effect on it's constantly increasing membership. When you are popular, people will go out of their way to find you. For the past eight years I have been a part of this great, ever growing amateur community sub-culture known as the Southern California FMers. I have watched the number of repeaters in this area grow from but a handful to over two hundred. I've tried to do my part by working with the local coordination people, and letting the rest of the nation know what one of its leading trendsetters is up to. Technològical advancement made by hams like those shown in Figs. 1-5 through 1-8 is a way of life out here, and much of what this nation's amateur repeater enthusiasts use in their day-to-day operation can trace its ancestry back to some obscure California hilltop.

Chapter 2
Modes and Relaying



The way in which amateurs communicate these days is markedly different from years ago. Our ancestors used the brute force produced by an electrical arc to generate RF. The equipment was called a spark transmitter, and used only dot and dash codes. As technology moved forward, the vacuum tube came into being and, with it, signals that were easier on the ears. It was not long before someone realized that audio could be superimposed on the waveform, and thus was born voice communication.

EARLY AMATEUR FM

In reality, the first attempts at impressing modulation on a simple power oscillator resulted in what might best be called "AM-FM." The fallacy of doing things this way (as outlined in Fig. 2-1) was manifold. V-1 is a simple RF oscillator whose output is link coupled to an antenna. Single-tube transmitters similar to this were quite common in the early days of Amateur Radio. Feedback to sustain oscillation was developed between the cathode and grid of the tube, and RF energy was electron coupled to the plate. C3, C4, and RFC-1 make up the feedback circuit while L1, C1, and to some degree, C2 determined oscillator operating frequency. Few, if any, Amateurs had discovered crystal-control in that era. To provide output to the antenna, C4 and L2 (with help from C-5) formed a parallel-resonant circuit at the operating frequency to transfer RF into L3, and from there to the antenna system. Crude by today's standards, but nonetheless effective in its day.

V2 functioned as a modulator. Audio of sufficient level was usually derived from a carbon-button microphone through the appropriate input-matching transformer. V2 then amplified the audio, which was transformer coupled to the transmitter plate supply, thus causing the supply voltage to vary, from its predetermined DC level at an audio rate. Obviously, varying the supply level at an audio rate will cause the RF level of the transmitter to vary at the same rate, and thus was born AM. There was only one catch: Simple oscillators such as this are not the world's most frequency-stable devices, and the modulation process had an interesting side effect. As the plate supply was varied by the modulation, not only was the amplitude of the signal changed, but it's frequency tended to shift at the same audio rate. It was not until oscillators and power amplifiers became separate stages in a transmitter, and crystal-contol took hold that true amplitude modulation (AM) came into being.

Throughout the 1930s, 40s, and into the mid 1950s, AM was the accepted mode for Amateur voice communications. Amateurs were constantly building bigger, more complex, and more powerful transmitters, but in the end, all could trace their ancestry back to the simple Master-Oscillator/Power-Amplifier rig, and its direct offshoot, the separate oscillator/amplifier combination. As technology advanced, Amateurs entered the world of VHF communications and brought with them voice communication in the form of AM. While SSB quickly replaced AM for low-band operation, AM hung on strongly within the VHF community, til' the dawning of the 1970s. Yet, today, in many parts of the nation and the world, AM is still considered a very acceptable mode of communication. Its not at all surprising to hear AMers still at its these days, using the same equipment they built or purchased some 20 years ago.

VHF OPERATION

Being able to operate mobile over short distances with simple equipment and relatively small antennas was one of the main drawing cards to get amateurs to step up in frequency. The normal line-of-sight characteristics found on VHF meant that one could get a group of friends together and always have a place to meet, free of unwanted skip. VHF soon became a large intercom, in many places, and out of this came many life-long friendships that might otherwise have never developed. VHF clubs abounded, and certain frequencies became the "in" meeting places. An example of this was 50.4 MHz, used during the fifties and sixties in and around the New York metropolitan area. Almost everyone monitored "400" in those days, and when someone you wanted to talk to showed up, you called him and then both "moved off" with your other crystal. In those days, only the "DX Kings" had VFOs!

While all this might have worked well in the New York/New Jersey area, where terrain is essentially flat, Amateurs on the other side of the continent had problems. The problems were called mountains and they had a peculiar property: They tended to keep VHF Amateurs on one side from talking to Amateurs on the other side. Oh, you could drive to the top of one of them and operate mobile or portable, but, in those days everything was of tube-type construction and required much power; you could not just drive to your favorite tree and plug in. Every bit of power had to be carried along, so, while many Amateurs did indeed go mountaintopping, they were the exception rather than the rule.

THE NEED FOR REPEATERS

Necessity, being the mother of invention that it is, tends to bring out the best in people, especially hams. Included in this best was a Los Angeles area resident named Arthur Gentry, callsign W6MEP. Then, as today, a broadcast engineer, Art realized that some practical way had to be found that would permit amateur signals from one area to be automatically re-transmitted so as to cover a far wider area, thus permitting communications over the hilly terrain. He reasoned that if an automated receiver-transmitter combination could be located atop a major hill—one that over-

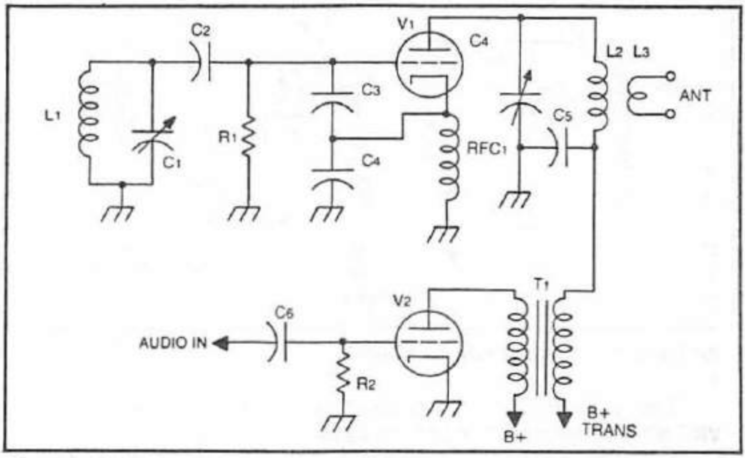


Fig. 2-1. A simple oscillator with modulator.

looked the LA Basin, San Fernando and San Gabriel valleys—then good quality communications could be initiated and maintained. It had been tried before, but only on a rather experimental basis; nothing long and sustaining. He already had access to a place to house the project; a 3000—foot "bump" called Mt. Lee, named after Don Lee, a pioneer in the broadcasting industry. This was the same hill that has for years been the home of the famed "HOLLYWOOD" sign. There were but two questions left: Could it be done, and if so, would it be accepted.

In the late 1940s, Art began his research into such a device. He devoted whatever spare time he could muster to the project, a project that took close to 10 years. Not only did he have to find or develop a receiver that would work well in the heavy RF environment created by the transmitter—a receiver that would not go belly up when the transmitter came on—but circuits were needed to control such a device, identify what it was, and do a myriad of other things that hams who purchase packaged repeaters these days take for granted. Then, too, AM, not FM, was the mode of the day, and this relay system was being designed to meet the AMers' needs.

In late 1958, from atop Mt. Lee, K6MYK signed on the air and ushered in a new era in amateur communication. Unlike repeaters of today, "MYK" was a constant-carrier device and the only way you could tell that someone had stopped talking was to listen for an audio tone between transmissions. K6MYK soon became a very popular meeting ground for Los Angeles area amateurs, and quickly developed a rather large following.

With all this, there was still one problem: Noise, especially when operating mobile. K6MYK was definitely an improvement over earlier, direct, point-to-point mobile operation, but the ever-present noise inherent to mobile operation remained. Most noise is amplitude related, and therefore AM receivers are quite prone to interference from it. To make matters worse, most of the noise component is vertically polarized. And, what polarization was the one chosen by Amateurs for use in mobile relay operation? Vertical!

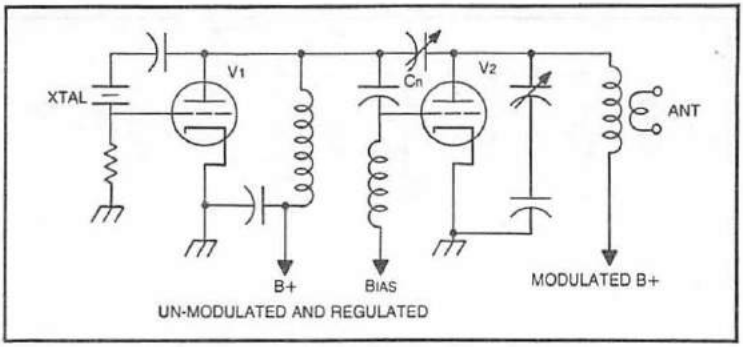


Fig. 2-2. An oscillator driving an amplifier.

There is another mode that has inborn properties to minimize recovered noise in respect to recovered signal. That mode is FM. It was not that Amateurs did not know about this property, but rather that there was little, if any, equipment available for use in that mode. Amateurs as they will, had become set in their ways and therefore accustomed to AM operation. Many had a heavy financial investment in state-of-the art AM stations, and scoffed at the need to change. Luckily, not all amateurs felt that way.

When a change in FCC regulations caused many pieces of commercial FM land-mobile equipment to be made obsolete, this equipment slowly but surely crept into the amateur surplus market. Until that time, names like Gonset, Polycomm, and Clegg had been the dominant brands bandied about on the air. But, as time progressed, the symbols of RCA, GE, and Motorola also gained places of respect within the amateur community. Unfortunately, much of this early equipment was converted to AM operation, or at least such attempts were made (not always successfully).

One of the more common methods to put a piece of then FM surplus on AM was to do the following:

A) Obtain crystals, or build oscillators, to cover the desired amateur spectrum and use this as a source of control signal injection for the local oscillator chains in the radios. See Fig. 2-2.

B) Retune the radios to the amateur band, and pad the coils as needed to effect this change.

C) Disable the FM discriminator, and use the discriminator transformer (or substitute a regular I-F output transformer) to drive an AM detector.

D) Build and install a rate-of-change type of noise limiter.

E) Direct screen-grid, or carrier-control screen-grid, modulate the final stages. In many cases it was easy to convert the usual 12AX7/12AU7 FM preamp to a controlled-carrier AM modulator with little work, and this method became very popular. If the modulator for FM used a speech clipper, it was bypassed. See Fig. 2-3.

In the fifties, and early sixties, this type of conversion was quite common, and worked—after a fashion. Had most Amateurs realized the quality of communications at hand, with no modification other than crystals and retuning, the FM move might have started years earlier. As it happened very few did, and AM remained king.

While this held true in most places, including southern California, there were some inquisitive minds that wondered what these radios were capable of doing in the mode they were designed for. Slowly, as with most evolutionary trends, Amateurs began to realize that, left alone other than changing the operating frequency, these radios could outperform almost anything that the state-of-the-art had developed to date. In the early sixties, more and more Southern California amateurs who were adventurous in nature secured a piece of land-mobile surplus and made way to the "high end" of two meters. They liked the concept of being able to establish an intercom channel that would remain silent unless in use: a squelch that worked! They liked the ability to go mobile without having to put up with annoying road and ignition noise, thanks to the inherent AM limiting afforded by FM. They liked the accurate frequency location offered by channelization, knowing that if a guy had his radio on at all, it was listening on "that" frequency. The ranks of FMers grew, and with this came the groundwork of many FM traditions as well as a new community within amateur radio—the FMer.

For many years, the FMer was considered the "outcast" of VHF society. First, by not wanting to compete with existing AM activity, he had for the most part taken his operation to the 146 to 147 MHz spectrum. AM operation centered around 145 to 146 MHz, with the rest of two meters used very little. Why? Most VHFers were Technician-class licensees, and, in those days, only 145 to 147 MHz was available to them. The "big-gun DXers" were down on 6 meters, and 2 was the local gab-band in most places.

Another bone of contention between AMers and FMers in those days was the channelized operation. This was looked upon by many as "naught but CB," and the use of "10 codes" copied from land-mobile operation did not help relations either; What every ham did not realize was that many early FMers were also involved in the land-mobile communication business, and that the 10-codes were quite common there. FMers and AMers were a world apart in their views and their technologies, and each preferred to keep it that way.

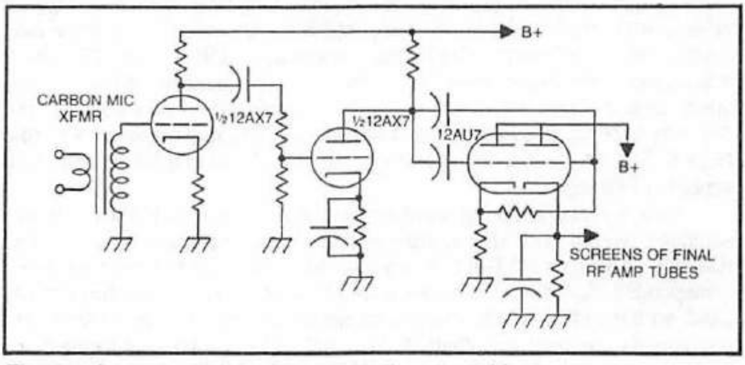


Fig. 2-3. Screen modulator for controlled-carrier A-M.

Eventually, it had to happen. If one could repeat AM from a hilltop, why not FM? To date, repeaters had remained a definite Southwestern AM fad that the rest of the nation said could never last. The feeling was that these "nuts" with their repeaters would disappear, and that "tradition" would be restored. Then, with the advent of W6FNO here in California, and several other such systems nationally, the FM relay era was ushered in. Things have not been the same since.

The advantages of FM over AM are such that a return to the past would have been impossible, and early FM pioneers like Ray Von Neumann, K6PUW, knew it. It was a matter of education—such as the time when Ray was working in Florida and was approached for information on how to convert ten obsolete Motorola FM radios to AM. Ray convinced the group to set the radio up on FM, explaining the success that California hams were having with that mode. He worked with them on the retuning and tweaking process in his spare time. He did not bring FM to Florida; only the knowledge of what the mode was capable of, and how to implement it. Shortly thereafter, one small area of Florida was staunchly FM-oriented.

As with anything, the word spread about the advantages of FM over AM, and the ease with which an FM repeater could be built. By 1969 and 1970, Communicators were being replaced with such early entries as the Regency HR-2 and Icom FDFM-2S. However, most FM advocates still favored converting commercial FM radios with one name, Motorola, being in the forefront of them all. As time progressed, two schools of thought emerged in FM: There were the purists who felt that anything not bearing the Motorola emblem was not worth owning; and, the "FM Ham" who could care less who made it as long as it worked. Today, these two schools of thought still exist, though today's "made-for-the-ham FM transceiver" is as good as anything that one can convert, and offers today's Amateur far more versatility at a price most can afford.

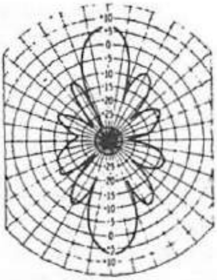
It is for this reason that the construction portion of this book deals with relay systems built from amateur, rather than commercial, gear. It is equipment that most amateurs are quite familiar with, and is found in their homes and vehicles. You will never hear me in any way condemn commercial equipment. It was only within the last few months that my own GE Mastr was retired from service and replaced with equipment bearing the name Clegg. Today's worldwide energy crunch dictated a smaller, lighter, vehicle with improved gas mileage, which in turn dictated smaller ham equipment, since I operate both 2 meters and 220-MHz mobile. The Mastr was a great radio, but it limited me to two 2-meter channels. With over 223 operational 2-meter repeaters in southern California to choose from, the day was here to go synthesized. I guess I am like most amateurs in that regard. Still, in its day, the Mastr served well. I can empathize with both schools of thought.

Now we are entering another new age. In the sky above us are satellites named OSCAR: orbiting satellite carrying amateur radio. The AMSAT (AMateur SATellite Corporation) people call the relay device a transponder. Actually, it is a specialized type of repeater operating cross-band, with the ability to relay or repeat any mode it hears. It is not limited to one specific frequency or channel; OSCAR looks at a band of frequencies within what is called its bandpass window, and relays each one to another discrete frequency. SSB and CW are the preferred modes when using OSCAR, since both are of low duty-cycle, and therefore consume a minimum of spacecraft power.

Amateurs have begun to wonder if the same technology aloft in OSCAR could not be made applicable to mountaintop relay operations. This thinking has been further spurred along by the advent of the amateur VHF multi-mode transceiver which packages all mode capability into one neat tabletop box. For reasons to be discussed later, SSB, AM, and other more exotic modes do not lend themselves to being relayed in the usual FM-repeater manner. However, the transponder or linear translator, will perform such a task as shown by OSCAR and countless other commercial space-relay devices.

Amateurs want the convenience of mountaintop SSB (and other mode) relay as well as FM. As this book is written, this dream is about to become a reality. Already, in-band linear translators exist in the experimental stage, and it will not be long before they are developed to a point where they can replace FM, and FM repeaters, as the center of VHF interest.

We are entering the age of space; the world is breaking the bonds that shackle us to this planet, and reaching out to the moon and beyond. Who is to say that the younger members of today's Amateur society might not be the space explorers of the future. Perhaps one of them will be the first to place an amateur relay device in operation on the moon, or some far distant celestial body. You and I may not live to see it, but it will happen: it has to. That's what the whole amateur radio service, and this book, is all about.



Chapter 3

Why FM?

What makes FM the preferred mode for point-to-point (simplex) and repeater communication? Let's list some reasons:

- Equipment availability
- Noise rejection
- Ease of repeater system construction
- Portability
- Reliability of communications
- Communications quality

The reason that FM took such solid root in Amateur communications in the first place was the availability of high-quality, low-cost equipment for the mode. When the FCC regulations governing operation in the land-mobile service were changed to reflect the need for spectrum conservation, much older equipment passed into the Amateur market. There was nothing wrong with this equipment. Most of it had been maintained "as good as new" throughout its operational life, and could go on for years more except for the new narrowbanding needed. Economically speaking, it was cheaper to replace most of this equipment rather than convert it to meet new specifications and then have each individual piece retested and realigned. So, it was phased out—and Amateurs got bargains they never expected.

THE 2-METER RIGS

In amateur service, there were no type-acceptance rules, so this equipment could be saved from the trash can and given a new lease on life. These "bargains" featured dynamotor or vibrator supplies, all-tube construction, and a weight factor that would add traction to any vehicle into which installed. They drew plenty of current, and at night, you could easily spot an FM mobile ham—his headlights would always dim when he hit the PTT button. But, they worked, and worked well. As long as FM operation in a given area was limited to one or two frequencies, they were more than sufficient. In fact, the overall quality of these radios was such as to spoil many an FM enthusiast for life. Some went so far as to buy one of the latest models on the market at the going commercial rate, and Motorola became to Amateur FM what Collins is to low-band SSB. If Motorola was the "Collins," GE and RCA were not far behind.

In the late 1960s, a few foreign and domestic companies introduced Amateur-oriented FM transceivers. These units were ignored by the then FM purists, but began to gain acceptance in the general Amateur community. Sales indicated a need for continued research, and soon many companies had introduced equipment to the market. Galaxy, Drake, Yaesu—names formerly entrenched in low-band operation—joined with Icom, Standard, and Regency to provide the amateur with a vast cross-section of equipment for amateur 2-meter use. Little attention was paid to the other amateur VHF bands. Activity centered around 2 meters, and in most of the nation around one particular frequency, 146.94 MHz, or "94" as it became known. This frequency developed into the recognized national calling channel for FM operators, either simplex or in combination with 146.34 MHz as a repeater pair. Today, if you have "94" in your radio, you can find a QSO almost anywhere, and, if you have "34" in combination with 94, you will usually find an open repeater. There are some exceptions to this, like in Los Angeles and San Diego, but it's the rule most places.

There is equipment available today to suit the needs of almost every 2-meter user. Equipment ranging from simple twelve-channel, crystal-controlled radios for use in less populated areas, to synthesized, hand-held transceivers for the traveler. Where the amateur of the past had but one or two channels to choose from, todays amateur usually owns a radio with a minimum of twelve. Most big city hams use synthesized radios capable of covering 144 to 148 MHz in 5-kHz steps without the need to purchase a single crystal. Even the necessary transmit offset for repeater operation is built in. As noted earlier, the most recent entry is the multi-mode radio which combines all-mode operation in one box, and which uses microcomputer technology to select and remember specific frequencies.

What's even nicer is its price. Even with inflation, the top-of-the-line multi-mode transceiver still retails for less than half the cost of a current-model, commercial land-mobile one-channel mobile radio. Thanks to technology, amateur 2-meter FM has come a long way.

What about other bands? Six meters is still covered mainly by converted commercial radio equipment. A number of manufacturers have been in and out of this market over the years, with little success. There is the age-old TVI syndrome, which has tended to keep 6-meter FM activity at a low level. Most 6-meter FM operators prefer commercial equipment, rather than that made for the Amateur, and the results are that little of the latter is available. Also, there is no really accepted national bandplan for 6 meters. Combining these three factors leaves 6 meters as virgin territory in many places.

HIGHER BANDS

The next band up from two meters is 220 MHz, and, in the same way that two took off some years ago, 220 is moving today. Unlike two meters, there was never any commercially made land mobile equipment available, and if one wanted to get on 220 just a few years ago, one had to roll his own. As two meters became overcrowded in many urban areas, a place to take some of the overflow was sought. Many looked first at the 420 to 450 MHz band, only to find it as crowded as two meters. Then something happened. Clegg Communications offered an interesting "package" which consisted of

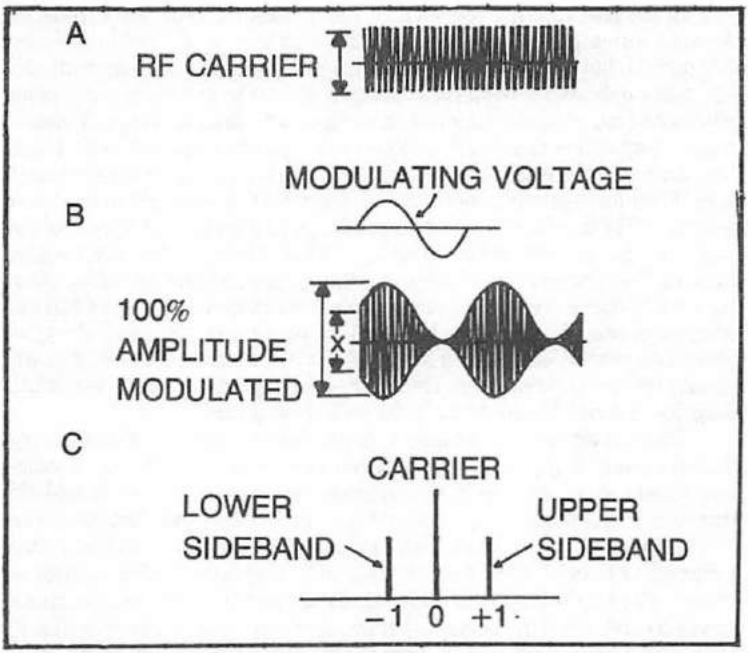


Fig. 3-1. Amplitude modulation waveforms.

a 220-MHz repeater and any number of their FM-21 radios for the group sponsoring the machine. While far from inexpensive, groups looking for a new road to explore purchased this equipment, and the age of 220 FM was born. About two years later, Midland introduced its model 13-509 transceiver, and with two entries in the band, 220 was entering its initial growth stages.

Today, along with Clegg's later model FM-76, and Midland's 13-509, there are the Cobra 200 and a hand-held manufactured by Wilson. If that were not enough, both Midland and Yaesu have fully synthesized radios at their dealers, and rumors are ever present regarding new entries into this fast-growing marketplace. 220 had to await the interest of the amateur manufacturer, but as those now in it know, it was a good move on their part.

At the very top end of what is today considered useful with current technology is the 420 to 450 MHz band. Like two meters, it boasts not only FM repeater operations, but modes and interests of all kinds, including fast-scan amateur television and ATV repeaters. In most places, FM relay communications of a nature that those involved call "Advanced Format" FM takes place.

Until recently, the 420-MHz FMer could only choose from an assortment of used land-mobile equipment, but, recently a number of amateur manufacturers have entered into that market. The two that at this time are making inroads are Kenwood and Icom. It's expected that others will follow and, while only FM transceivers are available now, due to continued interest in other modes as well as OSCAR communications, the multi-mode radios may soon be in the offering. Before that, we will probably see a generation of synthesized or programmable UHF radios, much the same as was seen in the development of two meters. With programmable offsets and sub-audible encoding as part of the package, "450" will be on the move.

NOISE

Next comes noise rejection. This is perhaps the biggest plus coming from using FM as a communications mode, especially in mobile operation. Why does this occur? Let's compare how a modulated FM carrier differs from one that is AM modulated.

As seen in Fig. 3-1, when we amplitude modulate a carrier, information is added to the carrier in the form of sidebands. Information in these sidebands is identical. In cases of voice communication, these sidebands are discarded. The information contained within the remaining sideband is where the information is recovered from. Unfortunately, most electromagnetic interference is also of an amplitude-varying nature. That is to say, most such interference is AM. Therefore, without some elaborate noise eliminating circuits the simple AM detection circuit cannot differentiate between the wanted intelligence and the unwanted interference.

Now, let's look at FM. We still use a carrier to act as a conduit for our information. However, in FM we modulate our carrier by shifting its frequency slightly from its predetermined operating frequency, and doing so at an audio rate, see Fig. 3-2. The detector in our receiver looks only for this variance in frequency, and ignores and changes in amplitude. Since most noise or interference is amplitude modulated, the detector tends to ignore it. However, no electronic circuit is perfect, and this holds true for FM detectors. For this reason, FM receivers incorporate other circuits known as limiters. A limiter is nothing more than an intermediate frequency

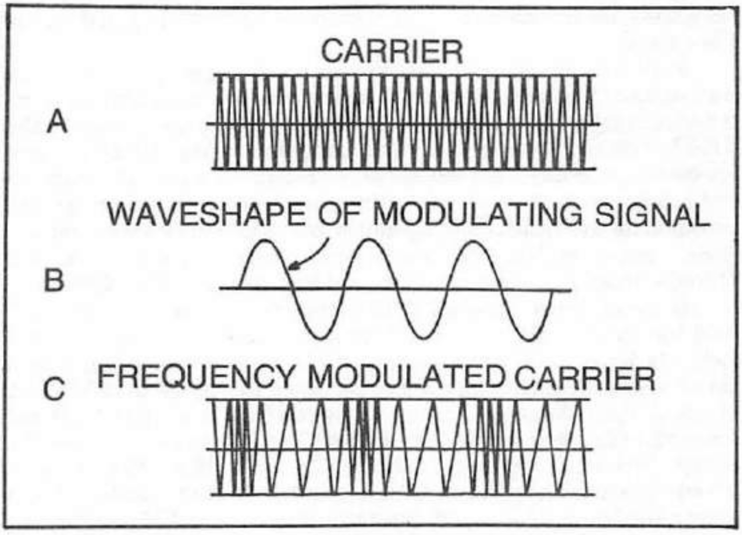


Fig. 3-2. Frequency modulation waveforms.

amplifier which is biased in such a way as to place the active component—be it a tube, transistor, or integrated circuit—at a point of saturation. Such an amplifier will then pass on an RF carrier, but tend to keep any amplitude variations from passing through. It is the combination of limiters, which reject AM, and detectors which look only for frequency variance, that accounts for the inherent noise immunity of FM.

As will be seen from the construction portion of this book, putting together an FM repeater is not at all complex. This is true today more than ever before, as shown by the many repeaters using receiver and transmitter boards garnered from current amateur FM equipment. A repeater can be as simple or as complex as you want it to be. It will perform any function you want it to do. You are limited only by your imagination. It can be a telephone, an interlink, or anything you desire. Repeaters are one of the few devices over which you, as an amateur, have the final say in its design. We will include some basic ideas, and hope that you will expand upon them.

PORTABLE MODE

The "Fun Mode" is also amateur radios most portable mode, thanks to today's advanced technology. In the old days, portable meant heavy "B" batteries, or bulky power converters. Not so today. FM operators were quick to recognize the advantages of portables and hand-held transceivers, and for years the marketplace has been full of such equipment.

Early FMers used such devices as Motorola P33-BAM portables, along with their GE and RCA counterparts. As hand-held transceivers became available, amateurs quickly grabbed whatever could be found, and equipment like the GE Pocket-Mate and Motorola HT series became quite popular. One unit, the Motorola HT-220, is still in a class of its own in FM circles, and is a hand-held which brings top dollar as used equipment. Though it was never designed for amateur applications, many FMers will tell you that the HT-220 is the desired radio; also the most modified radio in FM's history.

Many amateur-equipment manufacturers, recognizing that amateurs wanted more flexibility, were quick to respond with hand-held and over-the-shoulder portables, beginning around 1970 with the famous Drake TR-22. Still very popular and in demand, the original TR-22 featured six-channel capability (later models were 12 channel), excellent sensitivity and selectivity, built in Ni-cad battery pack with recharger, along with provision for external 12-VDC operation in mobile or fixed station applications. It came complete with batteries, microphone, carrying case, leather shoulder strap, telescoping antenna, and batteries, for under $200.

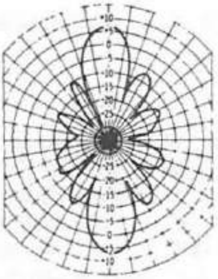
In the same era, Standard Radio Corporation introduced a true hand-held transceiver called the SRC-146; a five-channel, crystal-controlled radio which was the first true Amateur hand-held. Over the years, both of these basic radios have survived to be joined by entries from Midland, Heathkit, Pace, Wilson, and others. As we reach the close of the 1970s and enter into the 1980s, a new form of hand-held is with us. It's called the Tempo Syncom 1. Measuring only 1.60" × 2.5" × 6.5", this little gem affords full synthesis on all 2-meter channels from 144 to 148 MHz, in 5-kHz steps. The Syncom 1 is ushering in a new generation of FM portable, and who is to say what will be next. FM, especially 2-meter FM, is one mode that the amateur can take with him in his pocket and yet be assured of a contact almost any place in this country.

RELIABILITY

Reliability of communications and overall quality of intelligence are directly attributable to the technical nature of the FM mode itself. Since FM is largly immune to random electromagnetic interference, far better signal-to-noise ratios are possible with FM receiver systems, and obtaining a usable sensitivity of 0.5 microvolt is very common. In fact, there is really no direct way to compare FM to AM. In FM, you look for a given percentage of receiver quieting from an incoming signal. You are not looking at any noise other than that which may be generated within the receiving system, or the ambient noise floor of the spectrum being received.

In AM or SSB communication, you do the opposite. You look at the signal in relation to all noise, including that generated by electromagnetic interference. Your noise floor, as it were, is constantly changing, with changing interference characteristics. In SSB it is possible to minimize this problem through the use of a narrow receiver bandwidth, since we are only looking at the sideband we wish to recover. However, as we narrow the receiver bandwidth below 3 kHz, audio quality does suffer. While SSB has many advantages over AM, and some over FM in weak-signal work, for day-to-day VHF communications, FM holds the honor as the preferred mode.

Today's amateur FM communication has standardized at a nominal 5 kHz deviation characteristic (plus and minus 5 kHz from center frequency) for both 2-meter and 220-MHz operation, and this deviation affords excellent quality voice communications. Quality that is a close rendition of the original, and very pleasing to listen to. With proper receiver and transmitter design, this quality can be maintained with little deterioration. While certain other factors may enter into a given QSO, such as fade margin and multipath distortion, a good rule of thumb is that if you can hear an FM signal, you will understand what the other party is trying to say. Those of you who date from the AM days, and made the conversion to FM as I did, will recognize these advantages immediately.



Chapter 4 The Different Relay Systems

Often, when I give a talk on amateur FM communication, I begin by asking the question: "How many different kinds of amateur relay devices are there?" In most cases, the responses from my audience are: "Two—open and closed repeaters." Well, that almost right, since those two categories are correct designators. However, to be complete, one must add the following: Private Repeaters, Remote Bases, Linear Translators, and Simplex Autopatches. This gives us six different relay systems.

OPEN REPEATERS

Most Amateurs are probably aware of what an open repeater is. Simply, it's an Amateur relay device that is made available by an individual or group for use by any licensed amateur. In other words, the moral issue of system-support notwithstanding, it's a repeater that any ham can use if he holds the proper class license for operation on that particular band. In most cases, such systems are carrier access, however, due to crowded bands in some areas, some open repeaters use tone access of one type or another.

CLOSED OR PRIVATE

Still in the general area of repeaters, we find two other relay devices; they are the "closed" and "private" repeaters respectively. Yes, there is a difference between the two, though many amateurs do tend to lump the two into one category. To do so is a mistake in that there are definite criteria and operating styles to each. The closed repeater is a system which requires membership in the sponsoring organization to use the facilities. However, such membership is available to any interested amateur. Clubs or groups which sponsor autopatch operation or are involved in certain public-service works which require a controlled enviroment may require this, and, while anyone can join the organization, such membership is required before you may use the repeater.

A private repeater differs from one that is closed in that, while it, too, requires membership in the sponsoring organization, such membership availability is at the sole discretion of the system licensee. The rationale for this is twofold. First, an individual or group may have invested a great deal of both time and money in establishing a system, and therefore feel that it has an obligation to protect such an investment. Secondly, and more important, while all amateur bands are available for use by all amateurs with the proper class of license to operate in that band, nowhere does it say that any amateur must provide an open-access repeater for use by any other amateur. Over the years, the question of the legality of "closed" and "private" repeaters has come up time and time again. There have even been requests to the FCC for rule-making to ban such entities. All have been dismissed, and this dismissal is tacit endorsement of the legality of such systems.

In general, "closed" and "private" repeaters are "tone access." That is, it requires some sort of signaling tone to "wake up" the repeater's receiver and tell it to turn on the transmitter. Such tones, either burst or sub-audible, are considered private information and are not available to the general amateur populace. In most areas, private and closed operations are not abundant on the most popular repeater band—two meters—but there are certain areas where the exception is the case. Southern California, for example, has 22 such systems on that band. The concept of tone access and a description of the various types will be found later on in this book.

THE PORTABLE REPEATER

If a repeater is a device designed to be placed atop a tall structure such as a hilltop or tall building, why have one which is portable? Simply because amateurs like to enjoy every aspect of their hobby and also like to be in a position to serve any need at a moments notice. Therefore, a great many Amateurs have built portable repeater systems housed in brief cases or metal camera cases.

To all intent and purpose, these are nothing more than scaled-down versions of regular fixed-location installations. They still contain a receiver, transmitter, ID unit, timers, and a power supply. However, in most cases these devices are designed to operate on more than one channel pair. Most portable systems usually contain at least six possible channel pairs that can be switch-selected. This is because one never is sure exactly what channel pair will not be in use in a given area or situation. Take SAROC—Las Vegas, in 1977, for example.

SAROC is a major annual amateur convention and, back in 1970, the Palisades Amateur Radio Club of Culver City, California, showed up in force, complete with a portable repeater operating on their home channel pair. This idea caught the imagination of many convention attendees and, in the years that followed, more groups brought such devices with them. By 1977, one could almost find an active portable repeater on every 30-kHz, two-meter channel. At the 1978 show, there were also a number of portable 220-MHz and 450-MHz systems in evidence.

There is, however, an even more important use for a portable system—in time of emergency or natural disaster, normal communications can be knocked out. An earthquake could easily destroy a repeater site and all equipment in it. Or, the disaster could be in a remote area not serviced by established systems. Here the portable repeater concept really comes into its own, as was the case in the Marble Cone forest fire in California. Here, portable amateur repeaters became the backbone of an emergency communications network that truly benefitted the entire community. The portable repeater concept was proven beyond a shadow of any doubt as being a beneficial offshoot of today's amateur radio technology. Yes, a portable repeater at a convention or hamfest is fun, but the technology they utilize has been of immeasurable help to amateur and non-amateur alike.

REMOTE BASE

The next three categories are not repeaters, however, all do qualify as amateur relay devices. The first of these is called the "remote" or "remote-base." Actually, the proper designation for such systems is, the "individually owned and operated, advanced format, remotely controlled amateur base station radio." Quite a mouthful, but it is the definite second generation of amateur relay device, though some remotes do predate repeaters.

In their purest form, remotes are just as the name implies. One ham taking his base-station equipment to the best possible location, installing it there and then controlling it from his home in some manner. Such a system might consist of a two-meter transmitter and receiver located on the highest structure in the area, and radio linked to the owner's home on 420 MHz. That's the ideal. However, the modern remote of today is a far more complex item, both technically and operationally. Many remotes are owned and operated by more than one individual and therefore have access by more than one amateur. Operationally, most function as "private" UHF or 220 MHz repeaters when not in the downlink mode, with full autopatch facilities. For many such systems, downlink operation is not limited just to two meters, but may include 160 thru 10 meters SSB/CW along with 10, 6, and 2 meter FM. This gives the user the ability to carry but one radio, yet have full repeater, autopatch, and all-band/all-mode operation available at the press of a push-to-talk button. Some systems are so complex that the user can rotate a directional antenna, or tune a low-band CW/SSB receiver by means of the system's control circuitry. Others have the ability to interlink and form multi-state networks to extend their coverage.

Unlike repeaters, the average amateur operating on two meters has no way of working through a remote unless the remote wants to talk to him. Remotes are simplex devices in downlink mode, and require but one discrete channel on which to operate on any band linked to. This is not to say that a remote cannot be connected to work through a repeater, and, with many remotes being totally synthesized these days, this is quite commonplace in the southerwestern United States. In fact, until quite recently, the entire remote concept was limited to the southwest, with southern California being a particular hotbed of such operation for years. However, the concept has recently begun to grow, and remotes are starting to show up everywhere.

Like closed and private repeaters, remotes are generally tone access on their primary operating channels. However, downlinks are usually left carrier access. Remember, when you work someone who is talking via a remote, it is he who controls the QSO, and this takes a bit of getting used to for the average ham. Getting on a remote? It's just the same as getting on a private repeater. Either you wait to be invited or you build one yourself.

TRANSLATORS

Linear Translators are not new devices. They have been used for years to rebroadcast both FM and Television signals into remote areas.

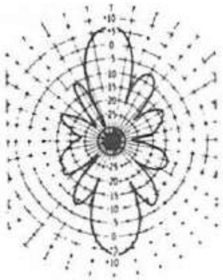
Amateur radio's first direct experience with such devices came in the form of the OSCAR series of amateur satellites. The current OSCARS have the ability to "translate," or repeat SSB and CW signals from 2 meters to 10 meters or 435 MHz to 2 meters, and many amateurs have come to enjoy the extended range of communication that these space-borne devices offer. How about a similar, ground-based device that would repeat SSB, CW, AM or any signal, but do so in-band, utilizing a normal repeater frequency split, i.e., 600 kHz input to output, which is the nationally accepted standard on 2 meters.

Thanks to today's technology, what was considered impossible but a few short years ago is fast becoming reality. Already, amateurs are experimenting with the design of such units, and by the time you read this book, the first such devices will be in operation here in California. In this book, you will find a chapter devoted to this new concept in all-mode relay communication. It will deal with the theory and basic technical detail of such systems, and will give you a glimpse of what the future has in the offing. Once developed and into wide-spread use. I predict that the inband linear translator will eventually replace the FM repeater we know today, just as SSB replaced AM on the HF bands some years ago. To my knowlege, this will be the first time that this topic has been covered in any Amateur publication.

SIMPLEX AUTOPATCH

Finally, we come to the newest of the new—possibly the most revolutionary of all the concepts to date: that of the "simplex autopatch." The simplex autopatch qualifies as a relay device, though it uses but one discrete frequency. While this concept, along with the necessary hardware, seems to have been developed simultaneously by a number of amateurs in different areas I am pleased to have one of the people who placed the first Southern California simplex autopatch into operation as a guest writer. Rather than discuss it further here. I suggest that you read the section on the Simplex Autopatch, Chapter 39, for further information.

The above six devices represent today's amateur family of relay operations. Within each, there are sub-categories and different operational formats. However, each general category is an entity unto itself, and each is deserving of the proper respect as a part of the overall FM scene.



Chapter 5
A Guide to Proper Planning

In the old days, it was only necessary to find a vacant channel pair; build your "machine", and go on the air. Unfortunately, this does not hold true today, and as time goes on it becomes harder and harder to find that elusive "spot" that one can call home for his system. This is because amateur relay devices in general, and two-meter FM-repeaters in particular, have become very popular over the past ten years. The packaged repeater has made it quite easy for just about any amateur to become an instant repeater owner-operetor. No longer must he convert land-mobile equipment to the amateur service. There is no longer a need to be a technical super expert in every aspect of relay communications. Required is simply a desire to fulfill some need; be it public service, service to ones fellow amateurs, or even personal ego satisfaction, plus the financial where-with-all to see such a project through to its completion are the basic criteria.

This does not mean that every repeater or relay device coming into existence today is the end product of a fat wallet. Nor does it imply that repeaters that are founded in that way are to be considered technically or operationally inferior to the system that is pieced together from land-mobile castaway equipment. In the same way that not every amateur is a technological wizard, not every repeater owner is either. If such were the case, I doubt if we would have the profileration of relay devices that we have today. On a level of operational equipment, it is easier today than ten years ago to place an FM repeater into operation. However, due to spectral crowding, things are actually a lot tougher in some places.

A FEW CASES

Let us now create and follow a couple of hypothetical cases to see how a new repeater might come about. While we speak of the FM Repeater herein, what we say applies to any relay device. To facilitate this discussion, we will be following two charts, Tables 6-1 and 6-2, respectively. Table 6-1 deals with the overall planning of a system, while Table 6-2 is directed to the technical aspects of system development.

Case 1: My name is Joe Ham. My callsign is WB6UBU and I live in Los Angeles. It is early 1979 and the radio club I belong to, the Radio Club of Los Angeles, has decided to put up an open repeater for our club members to use. Our members live all over the general area, from Riverside on the east to the San Fernando Valley on the west. We have some 300 club members;

many are engineers in aerospace related industries. Also a good sprinkling of professional and blue-collar workers. In essence, our club's membership represents a crossection of this city's society. Since most of our members already own 2-meter equipment, that is the band we will consider for our repeater. Also, since we live so far from one another, it is obvious that our repeater must go on the highest mountain we can gain access to. Our members demand that the coverage into each of them be totally saturated (fully quieting); they will accept nothing less. We realize, from repeater directories and on-the-air listening, that every repeater channel pair in both 2-meter sub-bands are already occupied with one or more operational repeaters, and that there already exist over 220 operational systems on that band in this area. What is our best approach?

Obviously, in this case, there are some very serious problems. southern California was chosen in this example because it is already at its saturation point for what are termed wide coverage repeaters. This is true today of other areas, including the Metro New York-New Jersey area, much of Illinois, and other centers of population. It is a typical big city problem that the big-city coordinator must face. Let's consult Table 6-1 and see if any solution is possible.

Joe Ham has already reached the decision with his club as to what kind of system it will be. Obviously, a rather super wide-coverage FM repeater. Its purpose is to act as a meeting place for members of his club. When asked if it will be available to other than club members, the answer is no, not unless they join the club. Therefore, it falls under the operational category of a closed repeater. Skipping to line 1D, we realize that it will be a repeater welcomed by Joe's fellow club members, but probably will mean little to anyone else. The answer really lies in line 1C: Is there already another system that can take on such a user load? Joe's Club already admits to having surveyed the entire 2-meter band and not finding any clear channel. Everything is in use, but to what degree? Are all the repeaters going day and night? Or are some used only occasionally? Would it not serve this club's purpose to locate a wide-coverage, low-activity system already in existence and strike some sort of deal with the system owner to support or maintain it in exchange for it's use as a club channel? This is the obvious solution, and one that seems to become more popular as time takes it's toll of available channel space.

Why should this approach work in this situation? Obviously we are dealing with a rather mature group: They known their own needs, but are also attuned to the overall local situation. Sure, they could procure a repeater and a site atop a mountain, select a channel pair at random and then wage war on all using it till it was cleared for their exclusive use, but doing so is kid stuff, and shows no maturity whatsoever. Why spend thousands of dollars to wage a war, a war that will bring hard feelings toward their club from the rest of the Amateur community, when there is a far more expedient method at hand. The solution was obvious, and in this hypothetical case it worked.

Case 2: I live in the rural Midwest, an area of mostly farms and farming people. Not many hams around the area, but we want to be able to talk with one another. We've tried simplex, but with amateurs scattered hither and yon, some just barely within range, it's a bit awkward. Then, too, the nearest repeater is close to a hundred miles away and there is a stretch of interstate highway that gets poor coverage from that system. Obviously, a need exists for another FM repeater in this area. Its purpose is quite clear: Not only will it give those of us who live here good communications, but also will be of aid to the many amateurs passing through on the interstate. Who knows, it might save a life someday. Thus, it's necessary, and it will be welcomed by all.

It will be an open repeater on some popular channel. We have no formal radio club yet, so perhaps this is the time to form one. Since I know more about repeaters than the rest of the guys I'll sponsor it with my callsign, WA8XXX/RPT. I'll get the boys together and we'll talk it over.

At the meeting, we decided that a new repeater is indeed a good idea, and since an ARES structure already exists, our club should affiliate with it. The group sponsering the repeater is small—ten or so—and each kicks in $50 to get the project rolling. We can't afford one of those bright and shiny packaged repeaters, so we elect to convert some land-mobile surplus. Len, who owns the CB and two-way shop in town, agrees to donate an old RCA Carphone and a pair of ⅝-wave ground-plane antennas. Frank has a couple hundred feet of RG-8U coax, which he will throw into the pot. All that's needed now are such things as a cabinet to hold it all, a few power supplies that can be built from discarded TV sets, some sort of blab-off timer to limit transmissions, and an ID unit of some sort. So, with $500 in the bank, and some equipment donations, the "Rural Repeater Association" is formed.

Mike has a windmill on his farm, and since it's the highest place around, it is selected as the site for the repeater. Actually, the machine itself will be in the barn, and the coax for the antennas will be buried in PVC pipe to the windmill. The transmitting antenna will be located at about 55 feet, and the receive antenna at the very top, some 75 feet or so. It's flat country for miles and miles, so the site selected is a good one. A letter is sent to the local frequency coordinator, and, in a short time, back comes a letter suggesting 146.04/.64. Well, it wasn't the .34/.94 or .16/.76 they hoped it would be, but at least it's a standard channel. It only took two weeks to get; not bad. Guess the coordinator has his reasons; he's the technical brain. That's why he is the coordinator. Now is the time to send for some crystals.

Len, Frank, and I have the job of putting the thing together and making it tick. We need a COR. The one in Sessions' *FM Repeater Handbook* looks good and it's easy to build—only one tube. Now for an ID machine: The local Emporium is having a sale on these eight-track stereo players. A latching relay triggered by the COR could turn it on, and the foil tape used to change tape channels could turn it off. Use a 30-second tape, and we have an ID machine, with voice, no less. Maybe we can get that young disk jockey at the radio station to record the repeater ID tape. Here's a nice timer that uses only two integrated circuits, and can be set from 2 seconds to 10 minutes. Looks as if we may have money left over when this project is finished; maybe enough to install an autopatch. That's for later on; right now we have a basic repeater to build, test, and install on 146.04/.64. Time moves on; it takes two months to get everything working properly, another six weeks to locate a suitable enclosure, and some small modifications to the original design must be made so that Mike can put a remote speaker, microphone, and on-off switch in his den in the house. All-in-all some five months have gone by from the time that the idea first popped into our heads until today, when we are celebrating our achievement. WA8XXX is up and running. It has a little desense problem, but we are buying some cavities to eliminate that with the remainder of the money. Len has already ordered them. We're having a party to celebrate, and we have some special guests; two young guys driving to California from New Jersey. No sooner was XXX on the air when they showed up on it. They needed someone to call the AAA because their car was stuck and wouldn't start. Looks as though I was right: WA8XXX has already handled it's first emergency.

Good planning and cooperation made WA8XXX, our hypothetical second example, a success. It was designed to serve an obvious need, a need not yet served in any other way. It came into being because the amateurs of that locality wanted it, and it's acceptance was total. WA8XXX will probably grow; it will eventually have it's autopatch, and probably a better antenna and a duplexer as well. Who knows how big it will get.

Case 3: Frank, Ted, and Al have been around VHF for many years. They live in the city, and when FM became popular they were in the forefront. They helped build and install the first 2-meter repeater in the area. In fact, Al still holds its license, though a club technical committee now performs all necessary maintenance on the system. Since that time, at least a dozen other repeaters have come to the area, and every week another new one shows up. It's not a big city, but one big enough to support an open repeater on every 2-meter channel. Even 450 MHz is getting crowded, and our threesome is looking for new mountains to conquer. They've heard stories about these "West-Coast-Remote Bases" that can interlink with each other and talk hundreds of miles. Just the other day, Al worked a guy, on 20-meter SSB, who claimed to be eating lunch on Wilshire Boulevard in Los Angeles, and was working through UHF hand-held unit to a mountaintop relay system. Other than the equipment on Verdugo Peak (of which he was part owner), his only other radio was the HT-220 he carried on his belt. In fact, the "6" told Al that the remote had capability of operating any mode on any band he wished. All he had to do was push the right numbers on the tone-pad to make it happen. Our boys are intrigued. This is what they are looking for to once again both stimulate their creativity and satisfy their egos. Only one problem: no place to do it on 450. Ah, but 220 is hardly used; now, that's the place.

All three are experienced repeater mechanics; they've done it many times before, both as amateurs and as professionals. Frank and Ted are partners in a two-way land-mobile shop. Al is chief engineer for the local TV network affiliate, and also has a good background in digital design. In fact, he had one of the first home microcomputers in the state. He is a wizard at anything digital. All three hold First Class Radiotelephone licenses; Frank and Ted are Advanced Class amateurs while Al holds an Extra. All three know the score on Table 5-1, however, this "advanced format" system they are about to undertake requires some good thinking. Let's develop it for them. Enter Table 5-2.

It's the 10th of December, 1978, as our trio meet at Ted's house to make plans. Al has been able to contact that "6" again and has arranged a sked with him so that all three can question him as to exactly what this seemingly unreal remote/repeater will do. At precisely 11 A.M. local time, Ted swings his TH6-DXX southwest and gives the W6 a short call. Immediately, there is a response and the QSO begins.

They learn that the remote system the "6" is using has sort of grown up over the years from a small, private, 450 repeater to a very mature system with almost unlimited capabilities. First, as well as being a repeater it has an autopatch as well. Also, it is affiliated with what is called an intertie which allows it to link on the 450 band to other similar systems throughout the Southwestern United States. The intertie is described as a cooperative effort among amateurs of that area to gain expanded coverage on UHF, and, in the case of this particular remote base, this means everything from California to Colorado. That's only part of the story, however. The twelve people who own and operate this remote wanted more flexibility, so they have installed a microprocesser-based control system which allows them to do a myriad of things. There is selectable downlink capability to any and all amateur bands from 160 meters thru 220 MHz. Also, virtually any mode, including CW and SSB, can be operated and, if warranted, all this can be linked to the intertie. As a "piece de resistance," all band-switching and frequency-selection is accomplished by remote control as is rotating the 20, 15, 10, 6 and 2 meter beams on the 120-foot tower atop the mountain. And, as if all this were not enough, all FM downlinks are synthesized to give total band coverage to 6, 2, and 220, including the ability to remotely select repeater offsets—even for the "odd one," WR6ABE on Mt. Wilson. As they sit listening, their eyes seem to light up, and it's only when the "6" tells them that there is some $40,000 invested in this jointly owned system that they return to reality. The QSO ended, they sit back and reflect over what they have been told. They want to duplicate it very much, but there is no way that the three of them can cough up forty grand, or more with inflation. Still they want something more than just another repeater, and decide to start on a smaller level and work toward a goal, in the same way that the group on the west coast did. It took the "6" and his friends some 15 years to get this all together. So what—Frank, Ted, and Al are not in a hurry.

Their initial band will be 220 MHz—no problem there, and they have already requested 222.94/224.54 as a channel pair. Their access category will be "private." It's their own hard-earned money going into this project, and they intend to protect their investment from any potential abuse. For that reason, they have elected to use Digital CTCS for system-control access (security), since it is something they can tailor to their specific needs. They will initially set up as a private 220-MHz Autopatch system, and expand from there. Since they own the best radio site in the area, on a 2800 foot hill, there is no problem. There is plenty of power and superb phone lines at the blockhouse. They already have a 100 foot tower next to the building, plus a few telephone poles, all of which hold the antennas for various mobile-radio systems. They pool the rest of their resources to see what they can come up with.

At the shop, there are numerous trade-in, land-mobile, high-band radios, including some fairly recent solid-state equipment. One of those will do nicely for a 2-meter downlink. They decide on a Harris RF Communications unit which will be frequency controlled by a synthesizer Al will design and build. Since there is little 6-meter activity in their area a two-channel General Electric TPL is chosen, which will be tuned to 52.525, plus the one local 6-meter repeater. They still need radios for 220 MHz, and though they are commercial types by nature, the land-mobile service has nothing to offer in that spectrum. They've heard good reports about the Clegg 220 repeater and the Clegg FM-76 radios and decide to invest in some. That takes care of VHF, but what about HF? Frank's wife has for some time been pleading with him to remove that HW-32, 20-meter rig from the Pinto so she can sit in the front seat next to her husband once more. Maybe it's time to do so, since with that, and his radios for the company frequency, and his 2-meter gear, there's hardly enough room for him alone. Ever so reluctantly, he agrees to donate it and a power supply to the cause. For the moment, it will just be set somewhere in the band, and later on they will devise some way to remotely tune it.

There's no doubt as to what kind of VHF antennas they will use; they've tried everything, and to them, nothing beats a XXX Stationmaster. Phelps-Dodge will be called early Monday morning and the antennas ordered, along with a top-of-the-line duplexer. They consider all sorts of antennas for 20-meter operation, and decide to use simple dipoles strung between the telephones poles. A switch controlled via the control link will switch the antennas for different coverage. This will be part of the control package that Al will build, along with the autopatch. Each has his jobs cut out, and, while this system will not yet rival the California "Do Everything" box, it is a definite step into the world of "Advanced Format" relay communications on a scale that is quite cost-effective.

Hypothetical? Yes, as was our "6-land" remote on Verdugo Peak, though the fact that such systems do indeed exist is far from hypothesis. They may not be as complex as the one described, but Advanced Format relay systems with all-band capability are a reality in my part of the world, as are intertie systems similar to what was described. True, the foregoing was fiction, but it shows how proper planning can lead to what you desire in a relay system. Your only limit is your own imagination and what you can realistically afford.

Case 4: You or me today. My name is Bill and I live in the suburbs of a very large city called Los Angeles. My town is called Newhall, and surrounding terrain effectively shields it from the greater Los Angeles basin(and just about everything else). A few of us out here have decided that we would like a local-coverage 2-meter repeater to serve the Newhall, Saugus, Valencia, and Canyon Country areas. Yes, there are other systems that service this area, but all are wide-coverage, designed to link this suburb to the LA metropolis. The problem with using them is that we are competing with Amateurs from all over the greater Los Angeles area for system time. There are constant, annoying breakers who want to call this station or that. It's getting to be nearly impossible to hold a QSO of any consequence. There are other, less active systems that also cover this area, but they were designed to serve Lancaster or Ventura, and it would not be fair to the hams in those areas to monopolize their machines.

It's early 1978, and already the area designated by the Coordination Council as being Southern California has close to 200 operational 2-meter repeaters. The FCC promises to open an additional portion of that band to repeater operation, but few of us have radios that will work in that segment without major retuning. We are willing to keep our system low-level and restrict its coverage. In fact, doing so is very advantageous, since we don't want to have half the state using it and making it another crowded system.

A letter is sent to the Southern California Repeater Association, and, in return, we receive a letter along with a number of forms. The letter explains that SCRA is out of 2-meter repeater channels, and suggests that we consider alternatives such as 220 MHz or 450 MHz. Going further, the letter states that if we cannot accept this alternative, we will have to research the entire 2-meter band and locate a channel on which we feel we can operate, and at the same time cause minimal interference to any other repeater already there. Further, we're cautioned that certain channel pairs are not available to use since, by agreement, they are used only by Baja Mexico. To help us, SCRA has sent a Request-For-Coordination Form, and Area-Wide Site-Activity Survey Form, and an updated repeater list. We are instructed to go to our site with a radio comparable in transmitter power/receiver sensitivity to what our repeater will be, and to check each repeater channel for activity. From this survey, we should choose a number of channels on which we think our system can survive, and then return all the forms to SCRA after completion.

It seems like a lot of work, but we do it, and find that our initial site is too good; if we go there, we cannot survive. Another, poorer site is located and we again try our survey. This time, two possible choices appear; 146.925/.325 and 146.34/.94. As much as we might like to go with .34/.94., in this part of the world that would be a no-no. Repeaters on that channel pair in and around Los Angeles never seem to survive. We notify SCRA of our desire to try .925/.325 and they issue us a 90-day test sanction.

Our repeater is one recently removed from commercial service and converted to 2-meters. A six-cavity pass-reject duplexer, and a newly designed 4-bay circularly polarized antenna complete the RF hardware. It's installed at the site, linked to a control system, and placed into operation for it's 90-day test. The test proves successful, that is, the other system on the channel does not complain about our sharing it. About three months later, the SCRA sends us a final sanction. We were one of the few lucky ones. If we had intended to cover a larger area, or had been across the hills in the San Fernando Valley, it never would have worked. But here, with a range of 4000-foot mountains between us and the other system, it was able to click, and, as long as we maintain our low profile we will survive even in this RF pit.

The foregoing are hypothetical cases—even the last one. I do not happen to own a local-coverage 2-meter repeater here in Newhall, nor am I planning one. While fallacy, these cases are based on many real systems that have happened over the years, and they illustrate the importance of spending the proper amount of time to consider all aspects of a proposed system before beginning any phase of its implementation. Let's review some of the major points in planning a relay system.

THE PROPER STEPS

First, is it necessary or does there already exist another system which serves the needs of the amateur community? Will it be an asset or a liability to you and the rest of your local amateur community? Can it gain the support of other area amateurs, or will it lack usership? Will it lead to technological advancement? Will it operate in the public interest and serve all peoples'

Table 5-1. Steps you can use in planning a repeater or remote base.

1) Decision:
   A) What type of device will it be?
   B) What purpose will it serve?
   C) Do other systems already exist in my area that can handle the activity?
   D) Is what I plan really necessary, and will my fellow amateurs welcome it?

2) Type of System:
   A) Repeater: Open____Closed____Private ________
   B) Remote Base______
   C) Simplex Autopatch_______

3) Type of Support:
   A) Individual Owner/Operator____ Club____Private Group________
   B) Affiliated With: No Other Organization: ____ARES____RACES____ Red Cross____School System____Other________

4) Actual Steps vs Approximate Time:
   a) Draw up system plans; 1 - 2 months.
   b) Apply to Coordinator/Coordination Council for channel pair; depending on area activity, the time to coordinate a repeater, or any relay device, can vary from a few days to several months.
   c) Produce the necessary hardware including radios, antennas and accessories; the time will vary, depending upon whether you purchase a complete, packaged system, or construct it yourself. Lead time on the purchase of a complete package ranges from several weeks to about six months. Home-brewing a complete system will vary, depending on its complexity—approximately 3 months is a good lead time.
   d) Locate/Lease site:
      1) Actual lease agreement; 2 - 4 weeks if you are lucky.
      2) Permits for operation on government land; approximately 90 days.
   e) Install and test equipment prior to final site installation, also called smoke testing; 2 to 4 weeks (weekends in most cases)
   f) Final installation at site; 2 to 3 weekends.
   g) If autopatch, give phone company 4 weeks notice for telephone installation, prior to the date you intend to install the system at its site.
   h) Have, or await, coordination before placing system into operation, to avoid interference problems. Hopefully you will have your exact channel pair so that crystals can be ordered earlier. This saves four to six weeks.

needs in some way? All of this should be carefully pondered before proceeding—before committing yourself and others to a project of this magnitude.

We have included two planning charts in Tables 5-1 and 5-2 which cover many of the parameters important to the planning of any new relay system. There are some we have possibly overlooked. If so, and should you think of them, add them to the appropriate chart. Any extra input will make your planning a lot easier. This approach has worked for others and I hope it will help you as well.

There are other aspects of relay-system planning that should also be covered: Is this to be an individually or collectively sponsored endeavor? If the former, then you are undertaking quite a responsibility for yourself. In the case of individual ownership, all aspects of system establishment and maintenance fall upon your shoulders. There have been many successful single-owner/operator systems established that have flourished. Some good examples of these are the original K6MYK, WA6TDD, and WA2SUR. All were started by individuals, and all are still very much alive.

Collectively, that is, by a group of amateurs forming some sort of system support organization, the overall job is quite a bit easier since the responsibilities for specific portions of the undertaking can be delegated throughout the membership of the group. Also very important is that the costs involved can be divided among the group, thus taking the burden of financial responsibility away from any one individual. Whether you "buy or brew," the cost of even a simple FM repeater can be quite high. The more complex you make it, the higher the costs gets. Keep in mind that, as you add periferals, it's not only the cost of the basic hardware but you must also consider the cost of modifications to the existing equipment to make sure of the additions.

Relay devices, even for the simplest FM repeaters, are not cheap. The average cost of home brewing one, using a good, solid-state commercial transceiver, is close to a thousand dollars, not counting such niceties as a duplexer or autopatch. Add these, and the price rises. Add more, and the price goes up proportionally. Of course, complete packages are available, such as shown in Fig. 5-1. It is no wonder that many who have desired to establish amateur relay systems join with others of a similar ilk, and form what is commonly known as the "Repeater Club." Let me detail the structure of such an organization for those unfamiliar with it.

Usually, a repeater club is made up initially of Amateurs with a common interest in relay type communication. It may get started because there is no repeater in a given area, because the ones already there are very busy, or due to the fact that a certain group wants to establish a meeting place of their own. There are countless reasons; these are but three common ones. As with any special-interest group, a set of by-laws are drawn up and a board of directors elected from within the initiating membership. The head of the board, be he called president or chairman, then selects an individual who is technically adept at relay communication, and appoints him as technical chairman. On his shoulders fall the majority of system related responsibilities—ranging from planning and design to final assembly and installation. Most such Technical Chairmen decide to form a committee to which they can delegate individual jobs that, when added together, become an established relay station. One person may be given

Table 5-2. A system-planning chart.

Licensee/Trustee Name:______ Date_______
Initial Band: 10M__6M__2M__220MHz__450MHz ______
Type of System: Repeater__Remote__Translator__Simplex Autopatch_______
Access: Open__Closed__Private__Other (specify)__________
Modulation: AM__SSB__FM__FM RTTY__FAX__Other (specify)________
Peripherals: **Radio Remote Control** on the____MHz band.
Linking Abilities___to the___________repeater(s) via radio link on the______MHz band, or by telephone interconnect
Control is: CTCS Activated_____Touchtone_____Burst_____other (specify)
Control System Is: Discrete-component Based_____I/C logic_____Microprocessor Based:
Downlinks/Uplinks To: 10M__6M__2M__220 MHz__450 MHz__FM and/or 160M__80/75M__40M__20M__15M__10M__6M__2M__220 MHz__450 MHz__Other (specify)________using AM__SSB__CW__S_TV__RTTY__FAX__PCM__Other (specify)

Equipment: Receiver for basic relay system:______________________________
Transmitter for basic relay system:______________________________
Antenna for basic relay system:______________________________
Control system for basic relay system:__________________________
Autopatch coupler for system:______________________________
Downlink/Uplink receiver (s) ______________________________
Downlink/Uplink transmitter (s):______________________________
Downlink/Uplink antenna (s):______________________________
Antenna Polarization: System:______________________________
Vert___Horiz___Circular___Other ____________________
Antenna Polarization: Uplink (s)/Downlink(s)
Vert___Horiz ___Circular___Other ____________________
Antennas for system are:
Omni___ Cardioid ___Mahor Lobe ____________________
Uplink/Downlink Antennas are:
Omni___Directional___Fixed ___Rotatable by remote control___Other_________
My Coordinator/Coordination Council Is:______________________________________
Address:____

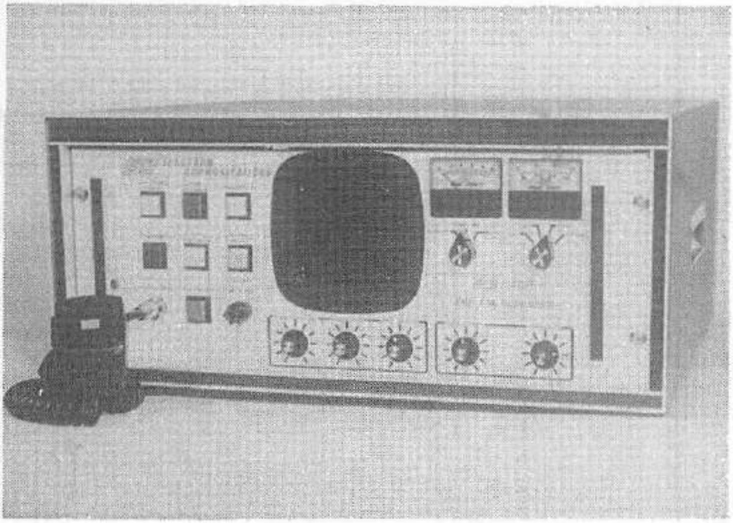


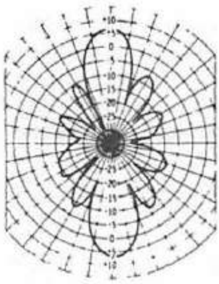
Fig. 5-1. If you do not want to roll your own, many companies offer complete repeater packages. This one is from Spectrum Communications.

the job of procuring a site, another may be delegated to work with the coordinator to obtain a channel pair, while others locate, design, and/or build the actual hardware. By dividing up the work, no one person has to play "professional ham" at the expense of his normal livlihood.

Financing the system is usually in the form of club dues, and this dues structure is determined by the overall complexity of the system that the group sponsors. Dues are usually ongoing since, after initial installation, there are always fixed operating costs. While it may vary from system to system, things that remain on a month to month basis may include rent for the site, power and other utilities, including telephone bills for autopatch or control telephones, and insurance for liability and/or the equipment itself. It would be nice to be able to give you an average figure for all this, but there is no way to collect the data necessary to do so. Therefore, if you elect to go the repeater club route, as many have done, then you will have to research your fixed costs for your particular system. One piece of advice—Take inflation into account; fixed costs are fixed, but far from stable.

There is one other type of group that should be mentioned. The established radio club with an "add-on" repeater. Here, the basic organizational structure exists, and the repeater is an addition to give better local communication among members, or bolster the overall membership. While the same logic applies as with the "Repeater Club," it should be remembered that, to such an organization, the repeater is an additional tool and should be kept in just that position. It is all too easy for an established group to lose sight of its prime reason for existence once a repeater comes along. The "machine" becomes paramount in the membership's mind, to the exclusion of almost everything else. It becomes a political nightmare with different factions within the club trying to gain political control over the system's operation. An organization that permits this to happen is foolish in that it will lead to its own eventual destruction. An easy way to prevent this from happening is to remember that the FCC does not recognize a repeater run by committee. In their eyes, the onus for all aspects of the system's operation is on the person whose call the system signs. It is best to turn the operation of "Club Repeaters" over to one trusted individual and keep the politicians out of it. Repeaters run by committee do not work, and I have seen a good number of well-meaning organizations meet disaster by taking on the responsibility of a club repeater without setting specific ground rules for its operation *prior* to its establishment.

In all cases, one thing to be remembered is that a relay device, be it a repeater, remote base, translator, or simplex autopatch, has no life of its own. It does not breathe, think, or possess any characteristics that even remotely give it any life form. It is an inanimate object; a black box designed by man to serve man. Always keep it that way. Human beings are far more important than repeaters—any repeater.



Chapter 6

Determining Your Needs

It's most important to think things out before attempting the establishment of any form of amateur relay system. I've stated some general guidelines, and now it's time to study them in more depth.

There are many factors that will determine what type of system you will build. The final product will be based upon many criteria, and each will play a very important part in the overall scheme of things. If you live half way between nowhere and the next town, and want to establish a system that will extend the communications of those passing thru your area, then anything less than a wide-coverage, open system holds little value. If all you want is autopatch ability, then a simplex-autopatch is far more spectrum efficient than a repeater. Why waste two channel pairs when one will do the same job? This is extremely important in the crowded urban areas.

For the experimenter—the person who is never satisfied with things as they are and tries to improve upon them—the linear translator holds a real challenge, especially if it is to be an in-band, rather than cross-band, device. The same holds true of the fast-scan television repeater. Just as audio can be repeated, so can a combination of audio and video. ATV repeaters are slowly, but surely, beginning to gain in popularity, and seem to be springing up in many areas.

CREATING A MONSTER

A rather graphic example of just how a system can develop can be found in the early story of WA2ZWP, the original Brooklyn, New York, repeater. It's a story I know well and will share with you as an example of needs versus cost efficiency. By early 1970, the New York City area FM repeaters were bulging at the seams with activity. It was all but impossible to hold any QSO longer than a few moments without finding that a waiting list had developed to use system. A small group of amateurs residing in Brooklyn, Queens, and out east toward Long Island, decided to put up a system of their own; one that would use a directional antenna pattern away from the metro-New York area thus limiting the service area of the system. Though it would be an open repeater, it was felt at the time that the very nature of the system's coverage would act to control both growth and usership, so that it would not get cluttered with activity and again become useless to it's sponsors.

The "repeater support organization" was formed to install and maintain the system. A group called the Kings County Repeater Association had many obstacles to overcome, not the least of which was that none of the group had ever before built a repeater. There were some very sound technical types involved in the group, but they had very little in the way of repeater experience. They had going for them an excellent site atop the 33-story Williamsburg Bank Building, excellent managerial and legal guidance, and some basic knowledge of VHF/UHF relay techniques. Also, one copy of the then newly published *Radio Amateur's FM Repeater Handbook*. On the other side of the coin lay the problems: The equipment they had the funds to purchase was rather old and in poor condition. Frankly, some of it looked as though it had been through the war and had lost. Then, too, there was the problem of obtaining a pair of channels to operate on. Though there were only a handful of repeaters that one could say were fully operational back then, still, the local coordination council had already assigned all available 30 kHz channel pairs and was beginning to develop the tertiary, or 15-kHz, channel pairs. A tertiary channel is one placed between two existing channels. This concept is discussed further under "Bandplans."

WA2ZWP was eventually assigned the 146.205/.805 MHz channel pair after many months of waiting. This wait had all but caused the ZWP project to reach a standstill, since the group really did not know which way to turn in regard to whether it would be permitted at all. Finally, the ZWP project began to move. It took close to another nine months before the repeater could be placed into operation. The months were spent cleaning up the old RCA radios and getting them back in serviceable condition. Peripheral equipment, such as a control system, an ID machine (voice IDs were very popular back then), plus the rest of what goes into making a repeater function had to be either built from scratch or converted from what was available at low cost. Eventually, close to a year after it's inception, WA2ZWP went on the air in test-mode operation.

All of this could have taken far longer had the technical minds behind ZWP not had the forethought to split the workload. In their case, two of the members who owned a TV Service shop had been assigned to get the RF hardware operational and connected as an operational repeater. Another was to build the UHF control system. Still others would prepare the site and install the antennas. Somehow, early in the spring of 1971, it did all come together and a new system came into being. It still had some problems, but it worked and it had been done at very low cost. The group had what it wanted in basic form, and over the years it would be improved upon. It was not meant to become one of the "super biggies," and never would be. Rather, it was a repeater designed to serve a very specific need, and engineered to that end.

CHANGING REQUIREMENTS

What happens when your needs change? When what was sufficient in the past no longer will do? Another interesting case is that of WB6ZDI/WR6ABB, the Palisades Amateur Radio Club of Culver City, California. ZDI was one of California's first "Big League," wide-coverage open FM repeaters, and has been a favorite meeting place for Los Angeles area amateurs over the years. It was the brainchild of two of this area's FM pioneers; Fred Deeg, N6FD, and Neal McKie, WA6KLA. The original ZDI repeater was made up of vintage Motorola land-mobile equipment. It had served PARC well for many years, but, by 1972 one could say that it had seen better days. The same held true for the rather weather beaten 4-pole antenna. PARC realized that the time was now at hand when a new repeater had to be either built or purchased, along with a better antenna.

A decision was reached that, rather than build new RF hardware, a complete commercial repeater would be purchased, along with a high quality base-station antenna. In addition, a totally new control system would be built to interfere with the repeater and provide expanded system capability. After researching all available equipment, Fred who had been placed in charge of the project, reported his findings to PARC's Board of Directors. The final decision, still subject to final membership approval, would be a Motorola Micor repeater, a Phelps-Dodge Super-Stationmaster antenna, and a totally solid-state control system designed and built by club members. In all, PARC was looking at close to a $4000 expenditure. Quite a bit of money, even for an organization the size of the Palisades Amateur Radio Club. However, PARC needed a system that would be reliable for periods of prolonged use by an ever growing club membership, as well as an ever-expanding area-wide usership. Reliability, especially long term reliability, was the overriding factor in choosing this equipment, and time has proven that it was a well-thought-out investment.

Finally, let's follow the development of another system. This one a private, 220-MHz operation—WR6AWQ. It was not the first system for it's owner, Jim Hendershoot, WA6VQP, but, by far, it was to be the most technically advanced that he had ever designed.

By vocation, Jim is a very competent land-mobile technician and equipment designer, and when he decided that he would build another Amateur system, he first spent many hours putting it together on paper. It would be built in specific steps, following a predetermined time frame. First priority would go to the basic RF device and its accompanying circularly polarized antenna. Next would come the control system and autopatch, and, finally, the various other downlink and uplink functions. Since there was little in the way of basic RF hardware available, Jim began AWQ by acquiring a Midland 13-509 transceiver and removing the receiver and transmitter boards. The receiver was reworked to provide better front-end selectivity and overall dynamic range, and the transmitter received a myriad of Hendershot modifications to enable the use of 600-ohm balanced audio input, higher duty cycle, and anything else he felt necessary to ensure long term stability in a hostile mountaintop environment. Special shielded boxes were custom manufactured to house each unit and provide the best shielding possible. Jim went so far as to have all sub-enclosures gold anodized to improve overall RF conductivity; an expense he felt worthwhile.

To this 15-watt output radio was added an 80-watt commercially made power amplifier, but not before it too had been altered in a number of ways to improve overall performance and longevity. A special heat sink of heavy extruded aluminum was fitted to the amplifier, and then bolted to a standard 19" rack panel for mounting. A thermostatically controlled fan was mounted as a subassembly as an additional safeguard. Prior to final installation, each subassembly was bench tested for several weeks to "cook out" any possible defects. In the interim, Jim, and Warren Andreasen, N6WA, had designed the necessary logic for AWQ—which Warren built. It, too, was carefully checked and debugged prior to final assembly.

Only after he was sure that every bugaboo was found and corrected did Jim transport the completed repeater to it's site and commence operation. Even then, it was far from complete. Next, an autopatch had to be designed that would meet the exacting criteria Jim had set for both himself and WR6AWQ. It was therefore a few months before the membership of the Canyon Repeater Association had such an ability at their fingertips. The same held true of the 2-meter remote-base function. Much time was spent on all aspects of what exact frequencies it would function on. Only after all parameters were set down did Lou Meiss, WA6EPD, begin the job of evolving the actual remote hardware from a Motorola Metrum II radio. Again, months had gone by before the 2-meter downlink was functional. One prerequisite that all CRA members had agreed upon was that nothing unproven would ever be installed at the site. Paramount to Jim and his system members was one word: quality. In all, some two years had gone by since Jim Hendershoot first decided to erect WR6AWQ. It has functioned almost flawlessly, with only two interruptions in service: one caused by a defective fuse holder in the logic power supply, and the other a partial system failure caused by mother nature. The 30-foot tower, upon which the systems four-bay, circularly polarized 220-MHz antenna is mounted, lost a guy wire in a wind storm, causing the once vertical tower to go horizontal. Thanks to the type of antenna chosen for the system, it remained operational—though coverage suffered markedly. It should be noted that it was not a failure in the system that caused this problem, but rather an uncontrollable and highly unforseen circumstance which caused it. Otherwise, AWQ users have been among the most fortunate in having an advanced-format relay system with almost unprecedented reliability.

Nor is AWQ finished yet. There are other empty slots in the rack that will eventually house interlinking transmitters and receivers to satellite repeaters now on the drawing boards; other remote base functions to 6- and 10-meter FM; low-band SSB operation, and more. However, as with the initial project of the repeater itself, Jim and his technical people are taking their time. They are carefully analyzing each step before it is taken, so that the end product is as reliable and cost-effective as possible. Everything has been carefully considered so as to make WR6AWQ a truly state-of-the-art relay system and, one to be copied.

You have seen how three highly diverse operations either took root or expanded. In one case you had a group of amateurs looking for a way to escape rather crowded conditions on other open repeaters, and succeeding with a minimal investment. Secondly, you learned of an established and respected organization with a need to substantially improve their overall operations. Lastly, there was a true experimenter, reaching to design an ultimate advanced-format relay device. Each attained success because each had a specific goal in sight before proceeding. All of this leads to but one idea: plan ahead.

STARTING OFF ON THE RIGHT FOOT

In this day and age it is easy for just about any amateur to connect a pair of radios together and call it a repeater. Many have, and still more will.

What is sad is that these "garage repeaters" serve little useful purpose other than ego enhancement for the builder. Unfortunately such systems also tend to die in the garage and the person who is spending his time on such a project would be better off teaming up with others of similar interest, and expending the same energy in a direction beneficial to all.

In that regard we have originated for this book what might best be called a needs or values planning chart, Table 6-1. It's not perfect, but it is a basis upon which you can determine if, indeed, your area needs your system, and moreover, if you want to be a system owner at all. Again, it was developed over many years with input derived from many amateurs.

Let's explore this chart and see what we can learn. The first question is self explanatory, and can be answered easily—especially if you own a synthesized or tunable receiver for the band that you intend to use. Yes, it is a simple question, however, it is also a very pertinent piece of data which is used as a comparison throughout the analysis procedure. The next question assumes that you have a basic idea of the type of system you intend to build, and gives you a direct comparison to the number of similar systems of the same type already in your area. Finally, we will try to determine if they are all being fully utilized, and, from this we can derive a certain relative spectrum-utilization-efficiency value. Now, let's insert some arbitrary numbers and see what happens.

Suppose you live in a area wherein some forty systems serve the same general usership. Of these, 25 are open repeaters, seven are closed, three are private; there are five simplex autopatches, no translators, and no remote-base operations. Your plan is for an FM repeater in the same general area. It will be an open repeater in an area that has a potential usership total of one thousand amateurs. With 25 similar operations, this brings the average user load per system to about forty. Taking this a step further, the average amateur winds up with approximately 0.6 hour per day of operating time on the repeater of his choice. This 0.6 hour converts to thirty-six minutes. The average repeater these days has a three-minute time-out timer to limit transmission lengths. Let's assume that average "Joe Ham" in your area drives twenty miles to work at an average speed ot fifty miles per hour. Normally, his point-to-point ride should take twenty-four minutes. Assuming normal usership during "drive hours," our hypothetical ham usually makes about six transmissions of about two minutes each during his one-way drive, yielding a total of twelve minutes of transmission time. The rest is spent listening. Assuming somewhat static conditions during each of his two daily half-hour drives, he uses approximately twenty-four minutes transmission time, and still has a twelve minute surplus for other operations. Based upon these figures, another open FM repeater is really not necessary. Remember, however, in our example we are dealing with ideal situations and not taking variables into account. In your analysis of your particular situation, such variables play a significant part in any final determination.

Our next three questions are again data-gathering, for use in further decisions. Again, let's stick in some numbers and see what we come up with. Our goal is the creation of a new open FM repeater, but so far it looks as if it might not get much use. However, further observations show that, of our existing twenty five open systems, only one has the ability to operate without the use of mains power in an emergency; none have autopatch

Table 6-1. System-necessity evaluation chart.

How many systems serve the same geographic area that mine will?__________
Of these, the demographics are:
___Open Repeaters___Closed Repeaters___Private Repeaters___Simplex Autopatches___All Mode Linear Translators___Other

Are all of the above utilized to maximum capacity?__yes ___no
Of the above, how many can operate on emergency power?________
Of the above, how many have autopatch capabilities?___________
Of the above, how many have public service affiliations?__________

The primary purpose for my new system will be:
____Public Service:___Technological advancement___Emergency communications.___Autopatch Operations___Personal ego satisfaction___Other operations.

To support my operation, I will be:
____Totally funding it myself,___Forming a user-support organization___Affiliating with an existing club,___Forming a closed corporation,___Relying on voluntary donations,___Other (describe below)________________________________

____

____

My system will be available for use by:
___Myself Only ___All area amateurs ___Club Members Only ___Select Users
It will be affiliated with:
___ARES ___RACES ___Red Cross ___Salvation Army___Law Enforcement ___Search and Rescue ___Other (Describe)

____

____

From the foregoing, will my proposed system serve any purpose?
Based upon all above, is it deemed wise that I proceed?
Other Comments:____

____

____

facilities, and only four have any sort of public-service affiliation. The emergency-powered one is not among that four. Applying this newly acquired knowledge, we realize that a public-service-related repeater with both emergency power and autopatch facilities might be very beneficial to the community, and also attract a substantial usership. Let's file this away for the moment, and apply it as we progress.

Now, it's time to look at ourselves in the mirror; time to search our minds to see what is really motivating us in this project. Is our motivation one of public spirit? Do we see a chance of serving the needs of our community and fellowman through our endeavors? Perhaps we feel that through our efforts some new breakthrough in technology might come about. Maybe it's just that we must prove to ourselves that we have the ability to do it; that, what others have done, we can do—and far better than any who have come before. Do not underestimate ego satisfaction as a motivating force, and do not deny it. Applying this to amateur relay communication, if you find, after research, that there is no room for your proposed system, and decide that you will declare war on an existing repeater to gain a spectral home, then you are causing unwarranted harm to others, and your actions are far from constructive. If, on the other hand, your sole motivation is ego satisfaction, and you are able to accomplish your objective without adverse impact upon others, then ego has served a healthy and constructive purpose. This concept not only applies to putting up amateur relay stations, but to every aspect of one's life as well.

One thing that a prospective system owner/operator must take into consideration from day one is where will the funding, both initial and ongoing, come from. This might best be called the "living-in-a-real-world concept," in that it costs money to build a relay system, and requires ongoing financial support to keep it operating. Here we get into a sticky area since it is against the law for an amateur to receive compensation for the use of his equipment or the communications he provides. It is for this reason that some system owners totally fund all aspects of their repeater themselves, and other amateurs totally refuse to support any such operations, though they may be constant users of the facilities.

While it is true that an amateur may not be directly compensated for his endeavors, there are legal ways that a repeater can be supported. In many cases, long-established radio clubs have added a repeater as a vehicle for keeping members in touch with one another, soliciting new members, and welcoming visitors to the area. In such cases, the system may be supported from the organization's dues or general fund. Such is the case with the majority of open FM repeaters today, and is a very successful method of obtaining the ongoing support that a repeater needs for it's continued existence. Another interesting method is one which started on the Los Angeles-based WR6ABE repeater some years ago, and has taken root nationally. It is the "User Support Organization." Under this concept, the system's owner-operator holds license and maintains the equipment but takes no active part in the political structure of the organization formed to support the system. Rather, it's a repeater user's club wherein the people who use the repeater collectively donate whatever is necessary to maintain and improve the operation of the system while leaving any and all decisions regarding system operating policies, both technical and operational, to the discretion of the owner operator. Both ABE's Mt. Wilson Repeater

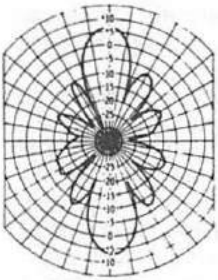
Association and WR6ABN's Mt. Lee Repeater Association are prime examples of how successful such organizations can be. Support is solid and ongoing, with neither system ever left wanting.

Another method that seems to be gaining popularity with private systems is that of a non-profit corporation. Actually it is usually a club structure under a corporate banner, with the corporation as the holder of the equipment. Since I am not an attorney, I cannot properly discuss the pros and cons of such a support structure, except to say that they do exist, and as long as they do not violate the rules and regulations as set forth by the FCC in Part 97, there seems to be no problem with this concept.

Finally, there is the old fallback, that of voluntary user contribution to the upkeep and maintenance of the system. This system still works quite well in areas where not many systems exist. However, in the crowded urban areas where one finds a repeater every 15 kHz on 2-meters, obtaining funding in this manner can be a chore. On a moral level, the user has an obligation to support each system he uses. However, if he uses twenty or thirty over a period of a year, he is hard put to decide which to support, since supporting all could easily break him. In many cases, he supports none at all, rather than playing favorites. This in turn is leading to another situation wherein a system owner finds he no longer has the financial support to keep his open repeater operational out of pocket, and elects to "private out." That is to say, he changes his format of operation to one of a select usership willing to give support, and closes his system's once-open doors to the community. While not yet a significant problem, it might become such in the future.

We have now gathered enough data to reach a final decision as to what we really want, and how to structure it so as to give it the best chance of success. We know, from our research, that an FM repeater with autopatch and emergency-power facilities, and which is directly public-service affiliated, had a good chance of meeting with success. Our original research in this hypothesis demonstrated this. However, we are also aware that such a system is beyond our personal finances, and will require considerable support to succeed. To that end, a club must be formed to install and maintain the system. While the repeater itself will be available to any and all who happen by, use of the autopatch will be restricted to club members from whose dues the cost of the system upkeep is met. With this support, we can procure some good batteries to provide emergency power, as well as a solar-power charger for them. With this type of system, our standby power will sustain itself at little cost, after initial installation. Finally, with a system such as this, we can be of service to one or more of this area's public-service groups, Perhaps ARES or RACES; maybe Mountain Search and Rescue. The list can be limitless.

We reach our final decision and it is this: Yes, there is a need for another system, providing we establish certain criteria, and then see the project through to that end. Otherwise, we serve no purpose, and our endeavors will not be warranted. In the end, what you decide may not be what you first intended, but it will be a far more viable entity if you analyze carefully your needs prior to picking up that soldering iron.



Chapter 7
Obtaining Hardware

As stated earlier, there are two basic ways to place a repeater into operation: either you can build it, or purchase it completely packaged and ready to go. In this chapter, we will look more closely at both avenues. First, though, we really should list the basic equipment necessary for a given system. This will vary from system to system, but certain basic precepts hold true. In our analysis, we will again deal with the most popular format today; the open VHF FM repeater.

SIMPLE REPEATERS

A simple repeater consists of a receive antenna connected to an FM receiver which tuned to a given frequency. This is called the "receive channel." Let's assume that our repeater receiver will be listening for signals on a frequency of 146.34 MHz. When our receiver senses the presence of a signal, it, in turn, turns on the transmitter which is connected to the transmit antenna. Since, on two meters, 600 kHz has been standardized as input-to-output separation, we will be retransmitting on 146.94 MHz what is heard on 146.34 MHz.

Therefore, in this analogy, we need the following equipment:

- Receive antenna
- FM receiver
- 146.34 MHz receive crystal
- Transmitter activation device (carrier operated relay)
- FM transmitter
- 146.94 MHz transmit crystal
- Transmit antenna

These are the basics. However, there are certain accessories necessary to make even this basic package work. They are:

- Rack or cabinet to house equipment
- Coaxial cable with connectors
- Optional hang-in and time-out timers to limit length of user transmissions
- Control package so as to comply with FCC rules and regulations

If you plan to build your own system at least in part, then you will first have to secure the basic RF hardware; this means a receiver and transmitter. There are many sources of such equipment, ranging from two-way land mobile manufacturers to your local Amateur equipment store or local swap-meet. Again, the determining factors are the money you have to spend, and the overall quality you expect from your system as an end product.

Choosing a receiver is perhaps the most important part of system planning. The three key parameters in this regard are sensitivity, selectivity, and overall dynamic range. Sensitivity is a measure of the receiver's ability to hear a weak signal, while selectivity is the ability of that receiver to select a wanted signal and reject others not on that same frequency. The third parameter, overall dynamic range, is a new one to many amateurs, but is possibly the most important. It deals with the ability of a receiver to deal with overall recovery of a given weak signal while dealing with far stronger signals within it's front-end passband, but which are unwanted. In other words, it's a measure of a receiver's immunity to degradation by unwanted signals.

Each of the above parameters have specific designations which define the particular job. Sensitivity is measured in microvolts. An example of this would be a receiver sensitivity rating of 0.5 microvolt for 20dB of quieting. This means that a 0.5- microvolt signal appearing at the receiver's antenna terminal will produce an overall receiver quieting effect of 20 dB from the overall noise floor. In FM receivers, the term quieting means the ability of the wanted signal to eliminate noise.

Selectivity is measured in kilohertz from the center-carrier frequency, and a receiver with published specifications that state an overall selectivity of 15 kHz is saying that the maximum receiver bandwidth is plus and minus 7.5 kHz from the center of the desired channel. In many cases, specifications will read something like plus and minus 6kHz at 6dB down, and plus and minus 60 kHz at 80 dB down, This is actually telling you quite a story if you know how to interpolate the information. It defines the receiver's overall selectivity curve in a way that it can be plotted visually. In essence, if you were to plot the figures on a piece of graph paper, the resultant would be a picture showing that, at the 6 dB down points, overall selectivity is 6 plus 6, or 12-kHz wide. At the 80 dB points, the overall selectivity is 60 plus 60, or 120 kHz.

Finally we come to dynamic range. How and where does this really fit in? To define it simply, let us suppose that at your site there are two other repeaters on the same band, and therefore your receiver's front end will see at least some of their RF energy. Now, let's assume that your receiver is quite sensitive and selective; perhaps 0.3 microvolt for 20 dB sensitivity, and 17.5 kHz at 6 dB down. Sounds almost ideal—a 2-meter repeater owner's dream. However, this dream becomes a nightmare when you note that the audio of the other two systems rides in along with your audio! For some reason, your super-narrow receiver is hearing things it's not supposed to. Obviously, you know the receiver's selectivity, and that the other two systems are far removed from it's passband; at least so you think. Experimentation shows that attenuating all incoming signals either eliminates or minimizes the problem, but also makes your system very insensitive. What is happening is that, while the overall receiver is not seeing the unwanted signals, the front end is. The unwanted signals mix with the unwanted one in the RF amplifier, and the whole mess then passes through the system since now the receiver sees it within the overall selectivity bandpass. A receiver which exhibits this characteristic is said to have poor dynamic range.

There is only one bugaboo to the foregoing. While manufacturers are proud to publish their specifications pertaining to selectivity and sensitivity, very few publish any figures pertaining to dynamic range. In most cases, such nondescripts as: "Good Overall Dynamic Range," or, "Excellent Dynamic Range," are used. These terms have little meaning, since there is no standard of comparison included. Therefore, for most Amateurs, solving problems brought on by poor dynamic range it is a hit-and-miss proposition. However, there is a measure and a standard, and most sources agree that aerodynamic-range figure of greater than 65 dB is an attractive feature. The higher the number the better, but there are certain limitations that prevent most receiver designs from going far beyond 90 to 95 dB. Nor is there any ultimate figure, since as the state-of-the-art improves, so does receiver design.

There are ways of figuring dynamic range, but to do so requires knowledge of exact design and operating parameters of the active and passive components, along with knowledge of the specific design of a given receiver. The computations are fairly long and are above the scope of this book. However, there are many fine engineering books which deal with this and allied subjects in minute detail, and to those interested, I recommend further research. To the Amateur who might happen across a piece of equipment with this rating as part of it's specifications, just keep the 65 dB figure in mind as a minumum. Applying these parameters to the procurement of an FM repeater receiver for use on two meters, let us suppose the available specifications read 0.5 microvolt for 20 dB quieting, and 35 kHz selectivity at 6 dB down. How well would that receiver perform in the two following environments if we assume it has an adequate dynamic range? One environment is a rural area with one repeater every 60 kHz, and the other repeaters, then this means a guardband of 25 kHz exists between crowded urban environment with noninverted tertiary repeaters every 15 kHz. If we halve the 35-kHz figure, we come up with plus or minus 17.5 kHz. If a separation of 6 kHz exists between system A and System B. To explain this further, let us assume that we are system A and our friend 69 kHz away owns system B. Both have identical receivers, and both use the same transmitter and deviation. Also, let us assume an absolute peak deviation of 35 kHz; again something never found in this day and age.

The math goes as follows:

System A—(minus 17.5 kHz) plus System B—(minus 17.5 kHz) (17.5 + 17.5 = 35; 60 − 35 = 25 kHz)

This 25 kHz acts to separate signals at receiver A from receiver B, and is called a guard band. Under these conditions, our rurally located receiver will function fine. Sensitivity is such that it will do an admirable job if nothing changes. However, should another repeater be established half way, or 30 kHz, between the two, then a more selective receiver is needed to reject the adjacent channel, or interference will result.

Let's carry this to another extreme, that of the urban area with repeaters every 15 kHz, non-inverted, and multiple coordinations on each channel. Obviously, we must tighten up the selectivity of our receiver or we will be constantly hearing the adjacent 15-kHz channel. The called for selectivity becomes on the order of plus and minus 5 kHz, or 10 kHz overall. Our 35-kHz wide receiver is a "junker" in this situation, and either must be modified or disguarded. Also it might be too sensitive. If there are three repeaters serving an area, and sharing a common channel, on-channel interference will result. There is no way to totally prevent it. However, making the system receiver less sensitive will help to minimize the problem, though it will also limit the overall system coverage. There are other methods that work better and they will be found under the chapter on tone access. However, if you are not into "covering the world," reduced receiver sensitivity is a tool for minimizing co-channel interference problems.

From the foregoing, one realizes that what may work well in one place may not perform at all elsewhere. Therefore, one must carefully analyze the present environment and projected growth patterns in selecting a receiver. To invest in something that seems to be a "good buy," only to find it's 40 kHz wide in a 15-kHz environment is a foolhardy investment. It is worth the investment to procure something that will work well now, and for many years to come. A good receiver is a long-term investment. If you think of worst possible future case when you buy, you will not find yourself back in the same position in two or three years.

Therefore, when looking for a receiver, the following should guide you:

- Sensitivity figure
- Selectivity figure
- Dynamic Range figure
- Established area channel spacing
- Established systems on adjacent channels
- Any channel sharing
- Total spectral activity
- Overall area bandplan
- Price

The rule of thumb is, the more crowded the spectrum in which you plan to operate, the less consideration must be given to cost. Good receivers are not cheap—even if you build them from scratch.

The other part of your basic hardware is the transmitter. There, too, price must be your last consideration. Remember, the average repeater transmitter runs at a higher duty cycle than your home station. If four people are in a QSO, then, over a given 20-minute period each may transmit for five minutes, but the repeater is transmitting the entire twenty. For that reason, it is wise to operate a repeater transmitter to it's nominal CCS, or Continious Commercial Service, ratings rather than to it's ICAS, or Intermittent Commercial and Amateur Service, power level. While the CCS rating provides less power output, it will enhance longevity.

Any transmitter will produce a certain amount of random noise, based upon it's design. At a single-site repeater, this additional noise will diminish the receive capability of the system, unless it is minimized. This can be accomplished through the use of sharply tuned filters and /or cavity filters placed between the transmitter's output and the transmit antenna. The more RF noise that reaches the receiver from the transmitter, the less effective the overall system. Therefore, using as clean a transmitter as possible is very important.

Another factor is the quality of the reproduced audio. Does the transmitter have separate audio-level and deviation controls, or only the latter? In most cases, only a deviation control is used, and an audio-gain control must be added. Having separate control over these two functions greatly enhances overall system adjustment. Again, the old adage holds true: One gets what one pays for.

Most amateurs contemplating relay-system construction have favored land-mobile FM equipment for many years; a good number still do. However, recent advances in solid-state technology have led to less-expensive receiver designs which perform quite well even under poor conditions. In fact, one radio, the Uniden (marketed under various names including Clegg, Cobra, and Midland), has become the backbone of 220-MHz repeater construction. It's 2-meter sister is now very popular for that band as well. For a very low price, these radios offer the would-be FM repeater builder the basis he needs for a quality system at a moderate price. It is for this reason that the Clegg FM-76 and Mark II were selected for use in the construction portion of this book.

Still, such gear as the Motorola tube-type "A" receivers and transmitters, and GE Pre-Prog equipment are very popular and still bring top dollar—though they are 20 to 25 years old. It's performance that counts, and over the years, these two have proven to be tops. Now-a-days, however, solid-state is replacing tubes, and some of the more popular radios are:

Motorola Motrac, Especially the UxxMxx series
Motorola Mocom, Motran, and Micor
G.E. TPL (Transistor Progress Line)
G.E. Mastr, Mastr II, Mastr Royal, Mastr Pro, and Mastr Exec
RCA Super Carfone and Fleetfone
Harris-RF Communications Land Mobile
ITT Land Mobile
Canadian Marconi

These are but a few names: there are others. It is important to remember that, to be used in U.S. Land Mobile FM Service, these radios must meet certain specifications to obtain FCC type acceptance. They are built more ruggedly than most Amateur equipment and as a rule, require less maintenance. However, even used, many of these radios still bring a premium price —in many cases, more than a comparable piece of Amateur equipment.

ANTENNAS

While it is possible to build your own repeater antennas most of today's system owners prefer to purchase them ready made—especially if the antenna is to be placed in a rather rugged and unfriendly environment, such as atop an isolated mountain. True, one could build such an antenna, but the cost in materials might easily reach that of a complete assembly.

Until recently, virtually all Amateur repeater activity was vertically polarized. For years, this sufficed, and it was only the search by some Southern-California-area system owners for a way to reduce mobile flutter and thereby enhance fade margin, that brought about the introduction of circular polarization at repeater sites. While not a cure-all for the ills of mobile relay operation, those who have converted their systems to it have found overall coverage greatly improved, especially in areas of rough terrain where repeaters sit atop high mountains and users operate from the valleys below.

The theory behind the use of circular polarization at the repeater is that no matter how many times a signal reaching the antenna changes in polarization due to bouncing and reflecting from the terrain itself, the antenna will always be in phase with anything it sees. Conversely, on transmit, the circular signal may bounce around and shift polarization, however, since it is circular to begin with, the user's vertical antenna will always see a vertical component of the received signal. A number of repeaters have proved this to be so, including WR6ABE, WR6AJP, WA6VNV/R, and WR6AWQ. All use, or have used, circularly polarized antenna systems and all attest to the improvement.

Vertical polarization is still the most popular with amateurs today as it is with the land-mobile industry. Later on, we will discuss equipment, including base and mobile antennas. However, at present we will deal only with equipment designed for the repeater itself. Along those lines it is just as important to obtain the best quality for antennas as with any other part of the system—possibly more so. Your basic repeater is isolated from the environment by some form of enclosure. You cannot say that for the antenna system. Whatever forces mother nature can muster will be thrown against it in its lifetime, and overall structural integrity is a very important consideration in choosing an antenna for repeater operations. Again, it's a matter of getting what one pays for, and one should not skimp on this need. It is for this reason that many repeater owner operators, especially those whose machines are located at remote sites, prefer using versions of antennas designed for land-mobile communications systems, but cut for the Amateur frequencies. Antennas known as the Stationmaster and Super Stationmaster, manufactured by Phelps-Dodge,are very popular though other similar designs by Andrews, Prodlein, Antenna-Specialists, and others, abound in great quantity as well.

Another determining factor is the location of the repeater versus the location of the user. This will determine the overall angle of radiation best suited for any given installation. The basic idea is to try to aim your system's RF to where the users will be. The higher up the system, and the closer in the users, the lower that angle should be. Then again, if your repeater is not that much higher than the hams who use it a slightly higher radiation angle is acceptable. A good rule of thumb is to try to keep the radiation angle such as to keep the major amount of RF within the scope of what one see's from the site to the horizon. In the chapter on antennas, these concepts will be covered in greater detail. For now, we should keep in mind that the antenna, or antennas, used with the system, along with the associated feed lines, should be of the best qualities. For antennas the exact type will be determined by system location versus desired coverage. For transmission lines, the lowest-loss cable you can afford is what you should aim for.

Where does one procure such equipment? If you plan to use Amateur type gear for your system, the answer is easy; advertising appears monthly in every Amateur periodical. Then, there is your local radio-supply house.

There, you can see and touch what you can only read about in the magazines. In many areas, Amateurs hold monthly, semi-annual, or annual swap-meets or auctions, and these are another good source of RF hardware, as is "horse-trading" among those who you know personally or on the air. Finally, do not forget to look in your own closet to see what you may have. Many of us still have operable crystal-controlled radios that, for one reason or another, have been taken out of service—perhaps to be replaced by synthesized equipment as activity increased.

Good quality, land-mobile equipment can be a bit harder to come by because sources tend to vary, and some will dry up quickly without notice. Companies like Mann Communications in Agoura, California, and Gregory Electronics in Saddle Brook, New Jersey, have been traditional sources for such equipment, as is Spectronics of Oak Park, Illinois. All provide high-quality, used equipment at fair competitive prices. I have personally dealt with all three, and have been satisfied.

Other possible sources range from the equipment manufacturer, where you will pay a premium price, down to such places as a local business on its way out, where you might be able to purchase their entire fleet of radio equipment at a bargain price (if you are lucky). In most cases, it is best to ask around, especially of other repeater owners as to their favorite source of supply. In any given area, those who have gone the same route before will know of any pitfalls along the way. As with everything else discussed in this book, I cannot over emphasize the need to carefully research before writing a check. Know your needs, and know what the equipment you are looking at is capable of. Do your homework carefully before pumping out those hard-earned bucks.

So far, we have looked at procuring RF hardware to build a system. What if you are not the building kind—all you want is the repeater itself, and not the job of building it. For you, too, there is an answer. It's called the packaged unit, and is available from many sources at different price levels.

Companies such as Motorola, GE, RCA, Harris, and others, manufacture such equipment for use in land-mobile communications, and are willing to sell the same units tuned to the Amateur bands. Repeaters like the GE Mastr and Motorola Micor command top dollar but also hold a high resale value, though over the years, very few repeaters change ownership after they are established. If you are willing to spend thousands of dollars for the very best of the best, then this may be the route you want to take. You are paying for top-quality construction and FCC type acceptance, but on-the-air results are usually top notch. If you plan to go this route, be prepared to spend over $5,000 for a complete initial system, including peripherals. By this I mean repeater, control system, antenna, duplexer, transmission line, auto-ID unit, and whatever else it takes to get on the air.

Sources of such complete commercial packages include, but are not limited to:

- General Electric
- RCA
- Motorola
- ITT
- Harris
- PYE
- Aerotron

Consult your local classified telephone directory for the particular representative in your area. Most have complete consultation and planning services, however, they may change fees for such services.

In the mid 1970's, a number of manufacturers entered the amateur FM repeater market. First among them was Standard with units for 144, 220, and 450 MHz, and Clegg with a 220-MHz system. Since that time, others have joined in with such names as Maggiore Electronic Laboratories, which produces units for 50, 144, 220, and 450 MHz; JBW, which specializes in 220 MHz only; Spectrum Communications which can supply units for 144 or 220 MHz; and others. Another very popular source of packaged amateur repeaters is VHF Engineering, which offers repeaters for all current amateur FM bands, either completely built or in kit form. Completely wired and tested, these units currently cost anywhere from about $550 up to $2,000, depending upon the band and on the peripherals ordered. Most manufacturers will pretune the units to the exact operating frequencies specified with the order, if you desire. Literally, one can purchase a repeater, put up the antennas, connect any desired accessories and be on the air almost immediately.

From all this, you can see that one need not be an electronics expert to own and operate an FM repeater. However, it is wise to know as much about your hardware as possible, since you are dealing with electronic equipment and, from time to time, even the very best requires maintenance. True, you can call in an expert if your pocketbook allows, however, there is a very special feeling about having the ability to fix it yourself when the time comes. Therefore, I state without any reservation, that while virtually any amateur today can easily become a repeater owner/operator, regardless of technical ability, not everyone should. When you place a system into operation, you take on certain responsibilities to yourself and to your users. Repeater ownership is one of the few full-time committments any amateur can undertake.

All this is great if you are interested in only an FM repeater. What if your interests lie elsewhere? Maybe you want a remote-base, or a simplex autopatch system fills your needs. Perhaps it's SSB you want to repeat, and you must obtain a linear translator. Unlike repeaters, these units cannot be store-bought,as yet. Remote bases and simplex autopatch units are FM devices, but, unlike their simpler ancestor, the repeater, their design takes a bit more skill. Remotes, for instance, are usually "system designed," that is to say, such systems are carefully designed prior to construction, and even the most minute phase or detail is carefully scrutinized so that the end result will perform to a specified objective. A remote-owner has a very good idea of what his system is capable of before the first connection is soldered. Since remote bases are one of the few pieces of hardware left that the individual can tailor to his personal needs and wants, it is hard to give more than a general inkling as to what such devices are capable of. In the end, it is best left to the imagination of the one who will ultimately construct it. While it is true that interconnecting a UHF repeater to a 2-meter repeater does constitute somewhat of a remote in the broadest sense of the term, it is a far cry from the day in which the remote base may well be amateur radio's most technologically advanced apparatus.

A good remote requires first a good repeater, operating on an amateur band above 220 MHz. At present, FCC rules preclude primary control of another transmitter on any band below 220. Most 220 remote owners favor the use of "made for amateur radio" equipment, while UHF 450-MHz systems tend toward the latest state-of-the-art land-mobile equipment they can acquire. As to antennas the 220 folk seem to be leaning these days toward the use of circular polarization, while 450 remains staunchly vertical. Most remotes also feature autopatch capabilities, along with the dozens of other functions they perform. In fact, when not in downlink mode, most remotes function as private autopatch repeaters.

Downlink equipment also will vary with the whim, and intent of the owner/designer. He may simply want one- or two-channel capability on 2 meters, with preference being given to 146.46 MHz—the national remote-base intercom channel. Then again, the remote owner may elect to build a system capable of operating every mode on every amateur band. It's completely up to him, and that is what is so nice about the concept itself. Therefore, equipment at the remote site can vary over a wide range, but certain pieces of equipment have become very popular with the advanced-format FM operator because they lend themselves to easy interface and remote control. A short list of these includes, but is not limited to:

- 220 Downlinks/Uplinks
    - Midland 13-509; 12-channel crystal control
    - Clegg FM-76; 12-channel crystal control
    - Midland 13-513; synthesized
- 144 MHz Downlinks/ Uplinks
    - Midland 13-500; 12-channel crystal control
    - Clegg Mark II; 12-channel crystal control
    - Motorola Metrum II; 12-channel crystal control with selectable offsets
    - Icom IC-22, IC-22A; 22-channel crystal control
    - Icom IC-22S; 22-channel programmable synthesized
    - Kenwood TR-7500 channelized synthesized programmable
    - Kenwood TR-7625; remote programmed, synthesized
    - Yaesu FT-227R and RA Memorizer; synthesized
    - Midland 13-510; synthesized
    - Clegg FM-28; synthesized.
    - Tempo One Plus; synthesized, remote control.
    - One Plus; synthesized, remote control
- 144 MHz SSB/AM/CW/FM
    - Kenwood TS-700 series
    - Yaesu Ft-225
    - KLM Multi-2000
- 50 MHz:
    - Regency HR-6; 12-channel crystal controled
- Multi Band UHF/VHF FM
    - Drake UV-3
    - 80-100 meter SSB/CW
    - Drake TR-7

This amateur equipment much of it of current production, has become quite popular with remote-base builders who want more flexibility than can be obtained with fixed-channel downlink operation. This gear lends itself to easy, or at least only moderately difficult, interface with an advanced-format system and has capabilities that amateurs of ten years ago could only dream of. It is no wonder that more and more of today's amateurs are discovering the advantages of such relay devices.

Advocates of simplex-autopatch systems seem to agree that one particular piece of amateur equipment excels in such service, after some modification. The unit is the IC-22S, manufactured by Icom. Simplex-autopatch operation requires high-speed receive/transmit switching and short receiver-recovery time. The simplex autopatch owners I have spoken with have had excellent results with the IC-22S, though other radio's have been tried with fair to good results. Again, you cannot yet purchase a simplex-autopatch system over the counter, but if such a device interests you, this book contains the basic plans necessary to construct one.

Of all the relay systems contained in this book, the most advanced is the in-band linear translator. There are no ready-to-operate devices or kits available in this category. No basic hardware of any sort, for that matter. All mode, in-band linear-translation devices must be home grown from the drawing boards up. Receivers must be exceptionally low-noise, and exhibit excellent dynamic range. In a translator, you are not looking at a single discrete frequency, but rather at a piece of spectrum which you intend to relay to another portion of spectrum. Therefore, while selectivity is not so much at issue in such receiver designs, the ability of a given design to hear equally well over its design range, and handle all levels of signal that appear in its bandpass, are paramount considerations. UHF design engineers such as Ray Von Neuman, K6PUW, recommend that you shoot for a dynamic-range figure of over 110dB. This means high expense and true state of the art; something now out of the range of most Amateurs. However, it has been done and,as technology advances, more Amateurs will involve themselves in this true "third generation" relay system.

Translator transmitters must be extra clean. Any spurious output is intolerable, and the design should be such as to minimize random noise generated within the transmitter. Again, this means true state-of-the-art, and spells out dollars. Most designs for FM-related equipment will not do since for a translator, Class-C operation is unusable.

I have found no other documentation pertaining to ground-based Amateur linear translators, so this book may be the first to provide working information on these devices. If so, I hope it stimulates further advancement in this new aspect of amateur relay communication.

THE COMMERCIAL LAND MOBILE FM TRANSCEIVER

Many amateurs have never heard the term " Commercial Land Mobile FM Transceiver," and wonder what it is. Actually, the explanation is not very complex. These are radios which are designed to operate in the various bands set aside for business communications. This equipment includes government, police, and fire, as well as various businesses. Radios for this service are designed and tailored for the exact portion of the spectrum in which they operate, and in no way resemble traditional amateur equipment.

Though there are various configurations of both mobile and base radios, most mobile installations use a trunk, or remotely mounted basic receiver/transmitter unit, and a control head mounted in a convenient place for the vehicle operator. The control head normally has but two or three controls for volume, squelch threshold, and channel selection. In cases where the radio is equipped with a tone-access encoder/decoder, there may be controls to activate this or other optional features. Both the microphone and speaker connect to the main radio through the control head.

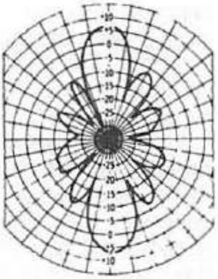
Base station configuration normally is a unit about the size of an amateur HF transceiver, but with few controls. Normally, one will find only volume and squelch on the front panel, along with a microphone connector. The only frills generally found are two pilot lights: one indicates power is applied to the radio, while the other indicates transmit mode. On base stations, the speaker is usually internal to the radio. Again, if it is a tone-activated radio, there may be an activate/defeat switch.

Most equipment available to amateurs, at a price they can afford, is either early vintage tube, hybrid, or solid-state. Almost all require modification to place in amateur service. This modification can range from simple retuning/recrystaling, to extensive circuit revision. In some cases, specialized test equipment, designed for the particular radio, is required to perform the retuning process, and a frequency counter, or other accurate frequency-measuring device will be needed to place the transmitter exactly on frequency. A general working knowledge of such equipment, or proper guidance from someone who has this knowledge, is recommended for those wishing to convert land-mobile FM equipment to Amateur service.

Early vintage, wide-band, tube type equipment will require the most extensive modification to meet current amateur standards, while later equipment, manufactured after 1960, will exceed all voluntary standards Amateurs now work by.

Chapter 8

Finding A Home



If you happen to own a mountaintop or skyscraper, then skip this chapter—you have no site problem. If, however, you are like the rest of us, then you must rely on property belonging to others for a home for your repeater.

Prior to looking for a site, it is wise to outline your intended coverage on some form of map. Nothing beats topographic relief maps. However, in a pinch, even a road map will do. Relief maps have the distinct advantage of showing actual terrain features. In mountainous areas, this is quite important, but for city dwellers, or those living in areas of rather flat terrain, it's not of great consequence.

To do your initial site location planning, pick a place on your map that seems to fit the area you intend to cover and, for the moment, consider this to be the site. Note the elevation, or, if need be, go out and survey the location. The next step is to try to determine what your coverage from that site will be; this is the hard part.

If accessible by road, drive to it and see what you can hear and work. This will give you a rough idea of the site capabilities, and generally, the coverage of all sites of similar altitude in your area. If possible, have a friend, or group of friends, work with you by driving away in different directions to see how far they can work your simplex. Use the same band as your intended system. If the exact spot on the map is not available, choose a spot as close as you can. We are not looking for perfection and super accuracy, just an approximation of what the local terrain does to RF. If you use a mobile radio with receiver sensitivity and power close to that of the intended system, you will wind up with a good perspective as to what can be expected.

Now that you have a basic idea as to what you can expect from the average site in your area, the time for earnest site-hunting begins. Here, again, what constitutes a site will depend upon terrain and area population density. If your plans call for a wide-coverage system to cover a sparsely populated area, or to interconnect to populated areas, then you will try for the highest structure in the area—be it man-made or a product of nature itself. Here in the west, such systems are usually located atop mountains, while in other areas such spots as tall buildings or broadcasting towers usually become system homes.

However, wide-coverage systems are not the only types that exist. In fact, there are a number of areas where, on certain bands, it is now impossible to erect such repeaters. These are areas in which virtually all channel pairs are utilized on that particular band, and those unused are subject to severe adjacent channel interference from existing wide-coverage systems. These are generally large cities such as Los Angeles or New York.

For this reason, many coordinators and coordination councils have developed specific criteria for systems based upon their coverage. In some cases, they no longer coordinate repeaters which intend to cover an entire geographic area. Simply, they can no longer do so without causing harm to already existing activities. Therefore, in many places, there now exist three types of coverage. While exact nomenclature may vary from vicinity to vicinity, the three are:

- **Inter-Community**: A wide coverage relay device designed to relay signals for as great a distance as possible.
- **Intra-Community**: A relay device with somewhat restricted coverage designed to cover a smaller geographic region, such as within the confines of a given city.
- **Local**: A relay system designed to approximate coverage that could be obtained thru point-to-point simplex. Its purpose is to serve as a centralized meeting ground rather than an effective range-extending device.

While a given coordinator of council may have far more exacting guidelines than these, they all boil down to the same as shown above. This is just one more reason why voluntary coordination is so important. Even in site selection, the guidelines set up in your area by these entities will play an important part, in overall system planning.

You now have two good pieces of information. You have, through experimentation, determined what coverage can be expected from an average site, and, through consultation with the coordinator and/or coordination council, you know the type of coverage which will permit your repeater to come into operation with minimal impact upon others in your area. Now, it's time to go site hunting. Depending upon your geographic area, such can range from a few phone calls and an elevator ride, to a weekend hike up the side of a mountain. In fact, to some hams, site selection is the fun part of putting up a new system.

Many times, amateurs have told me that it's been close to impossible to obtain the site they want. Though many reasons are given, they usually boil down to this: Locations offered free of charge or at a small rental figure usually will not suffice; the cost of commercial site rental is prohibitive, or all the "good ones" have been gobbled up already. While this may hold true in some areas where activity, both commercial and Amateur, is at a very high level, there is usually a way to overcome this obstacle.

COMMERCIAL SITES

Most amateurs looking for sites first contact commercial site owners. While, in some cases, they meet with success, in a great many situations they do not. The reason is that amateurs in general cannot afford to pay the same rates that commercial users can, and someone who has invested in commercial-site property must look at the overall return on the investment. Again, it's a matter of economics. Why should a site owner give special preference to amateurs? True, we do serve an important purpose. However, that must be weighed against profit from an investment. Then there is another factor that many commercial site owners take into consideration: Once installed, most commercial land-mobile relay installations are rather staid. That is, other than routine or emergency maintenance, they do not change much, and are not often visited by strangers. A high level of site security is thus maintained. Amateurs, on the other hand are experimenters, and as such, want total accessibility to their systems at all times. Most of us are never quite satisfied with things as they are, and are always striving for perfection. It's therefore not uncommon to have other site users object to an amateur installation for fear it will cause a breach in overall site security. Even amateurs who have been willing to pay commercial-site rental rates have been turned down because of this. This does not mean it is impossible to rent commercial-site space, but it does imply that getting special favors or privileges may be difficult or impossible. The same holds true in relation to sharing space at a broadcast-station location. This does not mean you should not try to obtain such favored treatment based upon the service you intend to provide, but you should be aware of the factors that will be considered by a site owner in reaching his decision. Hope for the best and use whatever salesmanship you can muster in presenting your case. Do not be discouraged if you find all of your arguments for naught. Most site owners are business people and must make decisions based upon what they feel is best for all users.

When dealing with a site-leasing company, remember that the end product you are looking for is a written rental agreement. This holds true for any site you lease, regardless of who the lessor is. If you are able to reach an accord, then, prior to signing any agreement, it is always wise to have the text checked by an attorney familiar with such matters. Though this may add a bit of cost to your project, figure it as good insurance. Leases, as with other legal documents, may be written in language and terminology we as amateurs do not fully comprehend, and legal assistance in the beginning may keep both you and the site owner from problems later on.

Most commercial radio-site owners are technically competent people, or have individuals versed in site use as part of their staff. Many such locations have a "Site Coordinator" assigned to them. It is his job to be sure that the system you propose to install will not cause harm to any existing installation. Therefore, you may be required to submit to him a carefully prepared engineering analysis of your system. Here in California, it is not uncommon for a site coordinator to demand the right to inspect equipment prior to installation, or to have photos taken from a spectrum analyzer, prior to giving any consideration to a new amateur installation. When trying to obtain space in any type of radio site, be it commercial, broadcast, or what have you, remember that you will be low man on the priorities list regardless of how important you think your system is. You will be given strict rules as to what you can and cannot do, and these are rules that you must obey without any question. These rules may cover such items as who is permitted at the site, hours of accessibility, esthetics and appearance of your equipment, antenna placement and a whole lot more. Experience has proven that it is useless to try to disuade someone from such regulations in that it is his private property and, as such, he must protect it. By far, the best sites with the best coverage in a given area will be of the land mobile relay and/or broadcast-facility type. However, they are the hardest and most expensive to obtain, and the most restrictive in nature.

These are not the only places to put a repeater. Maybe there is an amateur in your area who lives in a good location or has a high tower. If so, you might be able to negotiate a deal for use of his tower space, or his home or garage as a system location. It is even better if that person does not operate on the particular band on which the system does, since there is less chance of interference to him that way. In cities with high-rise apartment houses, you might be able to place the system in a friend's closet, and cover his cost of operation, even if he is not an Amateur, as long as individual antennas are permitted to tennants of that building. Locations such as these will give you better availability to the system proper, but many adversely effect coverage. There are many different structures which can be used as a site, and it's really up to you to keep at it until you locate one. Eventually, something will come along to fit your needs.

One often-asked question is, which should be done first—site selection, or equipment building? As with anything else, I favor making it a three-step process and taking my time. This should hold true with all aspects of system planning. First, prior to procuring any hardware, it is wise to take a cursory glance at what is available in your area, and what might be obtained from within any organizational structure your proposed system might have. Maybe one of your members or system partners has the necessary site, and no further looking is necessary. Then, again, you might find that every good commercial or broadcast site is unavailable. A rule of thumb for a good system planner is to know what "might" be available prior to starting the overall project, so that the system can be designed to accommodate the type of environment it will be a part of. After you have a general idea of where it might be, begin a twofold project of system construction and site selection. Usually, by the time the basic hardware is ready, a site will have been secured, and, should it be one which requires that the site coordinator inspect the equipment and/or perform tests on it for site compatibility, it will be ready for him to do so.

GOVERNMENT LAND

If you plan to operate from a site that is on government-owned or controlled land, then you will need more than just a site-rental agreement. Also required is a permit from either the U.S. Forestry Service or the U.S. Bureau of Land Management. Since you are dealing with the government on this, it is wise to give yourself plenty of lead time in planning. While some amateurs have claimed to have obtained an agreement in less than a week, others have told me that it was a process that took years. If you give yourself between 90 to 120 days, this should cover it. One word of warning, however: It is a violation of Federal Law to operate from government land without obtaining such a permit, and doing so leaves you liable to rather severe penalties. No amateur relay system is worth a fine or jail term. Be wise; get that permit before commencing operations.

INSURANCE

Finally, let's talk about site and equipment insurance. Never depend on insurance that others might have, including the site owner. If, by some unforseen chance, your system should cause damage to someone else's property, you could be held liable. If someone was injured or killed as a result of any aspect of your installation, you could be held responsible. If the equipment is stolen from the site, who will bear the cost of replacement? These are aspects of system ownership that any individual or club undertaking such a project should consider.

Depending upon your locality, and the insurance laws in your state, it is usually possible to obtain insurance through a bonafide company to cover all aspects of your installation. This would include, but might not be limited to:

- Fire-theft-vandalism-earthquake damage to equipment
- Negligence (in regard to damage attributed to your system)
- Personal-injury/negligence (resulting from accidents caused to any individual as a result of your system's installation or operation)

Such insurance is not inexpensive, however, it sure beats the cost of defending oneself in a court suit. That could cost many times the amount paid annually for insurance. Most Radio-Common-Carrier operations, Land-Mobile Sales and Service Organizations, or possibly your own insurance agent, can direct you to a source of such coverage. Again, be wise and spend the money needed for this.

Table 8-1. Some guidelines for site selection.

The area I intend to service is: densely populated___ sparsely populated______
My system will be: intercommunity___ intracommunity ___local ______
I expect my coverage to be:____miles or____Km.
I need a site approximately_______feet above average terrain.
I/our organization can afford $______per month rental.

Type of site desired:
a) Land-mobile relay site_______ b) Broadcast facility______________
c) Private home_______ d) Tall building__________________
e) Private apartment______ f) Other__________________

If Land-mobile relay site:
a) Cost of monthly rental $____________
b) All weather accessibility: good ___fair___poor______
c) Is the cost of utilities (power) included in the rental fee?_________
d) Is there telephone service available at the site?_____________
e) Is it on Forestry or Bureau of Land Management controlled land?______
f) If so, a permit is required. Have I applied for same?______________
g) Are there already antenna-mounting structures at the site or must I supply them? ____________
h) Does the site owner require site coordination?_____ If so, have I contacted the Site Coordinator? ____Does he wish a technical evaluation/presentation of my proposed system?___Does he wish to inspect it? ______When and where?____

ALL POSSIBLE SITES?

What is my accessibility? Always____Limited___If so, to what?_________
Have I a signed lease?__________
Has this agreement been checked by my attorney?_________
Have I arranged for insurance to cover:
a) Fire-Theft-Vandalism to equipment and accessories
b) Negligent property damage
c) Negligent injury to others

My annual insurance cost is? ____________
Is this the best possible site to suit system needs now, and allow room for expansion? _____If not, why?______________________________

Now that we have gone over some of the aspects of site selection, let's develop some guidelines in chart form (Table 8-1) to help with this part of the project. The chart will include certain items not covered in this text, since they are "regional items" and may not apply in all cases. Use the chart as a general guide, deleting what does not seem to apply. Another important factor is keeping a site once you have it. True, there are certain unforeseen eventualities that can cause a site loss, such as the property being sold and the new owner not wanting you any longer, but these are few and far between. In most cases where amateur systems loose a site, it is because they have in some way become either a nuisance or burden to the site owner. One sure way to fall into that category is to bring every ham in the area to the site to show off the new machine. What's wrong with that? Simply this: Most site owners, especially those who rent primarily to land-mobile or broadcast-systems, guarantee a certain degree of security. This means limiting site access to certain authorized personnel only. Included in this group are usually service personnel for the various systems located at the site, the site technical coordinator if one exists, and the site owner himself. In many cases, long-time personal acquaintances have developed among this group. They know and trust one another. All of a sudden, you come along; they do not know you or your technical ability. You are a stranger to them, and thereby pose a possible threat to the overall security of the many devices located at the site. To them, radio is a source of income, not a leisure pastime. So, in their eyes, having you there is "bad enough." Can you imagine how one of these other non-amateur site-renters would feel if he witnessed two busloads of hams pull up by the door, and what he possibly considers "a bunch of know-nothing hams" come tromping into the building? Such experiences often wind up as formal complaints on the site-owners desk. Such complaints don't sit long, either, as many system owners have found out. Usually, it's a phone call which lays down the law, and says "straighten up the act or ship out." That's if you are lucky. Most of the time it is to the tune of "have your system out of the site by dusk!"

COMPLAINTS

How about a situation where you have thoroughly bench-checked the whole system, and it operates flawlessly at your home. You move it to the site, put up your antennas, and find yourself beat to death by the system in the next rack. The neophyte system-owner might hurry to the nearest phone and call the other system owner to inform him of the problem. That's fine if the other system belongs to another ham. What if it is an RCC installation, however? What kind of result might you get complaining to them? For one thing, probably a patronizing deaf ear. Why should they listen to you. You are "just a ham" and they are business people. If your hobby is going to cost them money, then they would just as soon you disappeared. You might get through to their maintenance department, and the first thing the engineer or technician on the other end of the phone line will ask is, "What steps you have taken with your machine to eliminate the problem?" If you get this far, and that's not very likely, you had better have some sound answers for him, and also know how to talk his kind of language. He may ask what type of cavities you have ahead of the receiver or what is the exact nomenclature the duplexer you have, along with its exact pass/reject characteristics in dB. He might want to know the exact dynamic range figure for your receiver, or any of hundreds of bits of information that you had best have on hand. Never berate the quality of his equipment or his installation. It might be junk—he may know it's junk—but he will never admit it to you, even jokingly. His job is to keep it operational and within predetermined FCC regulations. Even if he is an amateur, his first duty is to his employer, and if his system does meet FCC criteria, then you are on your own. His next call will probably be to the site owner with a direct request that you be removed from his back. Basically, calling the interference source directly—if it is other than an amateur system—is a bad idea; one that may haunt you for a long time.

The proper method is to learn all you can about proper RF filtering techniques, and apply what you learn to your system. Try everything you can, and seek whatever avenues of help are available. You might call the other system owner and speak with his technical people, but do so as someone looking for information on the problem without mentioning that he is the source. Better yet, contact another amateur with a long-term successful system in your area; someone known for his expertise in such matters, and request his aid. If, after taking every avenue open to you, it is impossible to solve the problem, speak with the site owner or his technical staff and explain both the problem and the steps you have taken to eliminate it. *Do not lodge a formal complaint against the other system*. Simply ask for their help in solving the problem. I say that you should not complain, since, if there is no feasible way to solve the problem, and you find that it will necessitate changing sites, it's best to leave on a friendly basis. If you cause major problems for commercial users, you might find it hard to obtain another home. Commercial-site owners do talk to each other, and frequently ask each other about new rentals.

Some cases in point will illustrate this. One of the contributing technical writers for this book happens to be part owner of a 220-MHz repeater/remote base which is located at an excellent site, along with a UHF television transmitter. When first installed, the system suffered from a 59-Hz tone coming from the TV transmitter. The repeater group was using solid-state equipment, and no amount of shielding or filtering would remove the 59-Hz from their signal. Wanting to make a "go" of the site, they used their collective expertise and decided to step back one generation in the evolution of electronic relay devices; they reverted to tube-type equipment which exhibited better immunity to the TV transmitter's vertical-sync signal, and thereby solved the problem. Today, the system works flawlessly, and is being expanded. Sure, it took time—time to trace down the problem, and more time to cure it. They complained to no one, and thereby saved a good site.

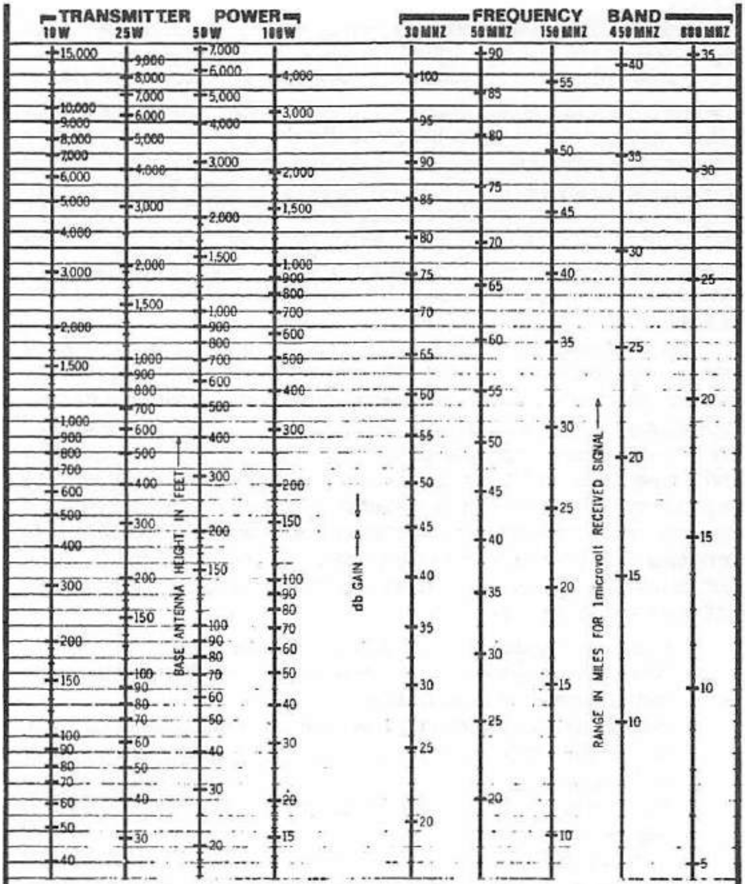
There is another story about a group who purchased a repeater and took it to it's new home. It was a rather poorly designed piece of equipment, and was prone to all sorts of receiver problems. In this case, the group constantly complained to the other services at the site about the interference. They did nothing at their end to try to eliminate it. As this story was told to me, one day one of the Amateur-system users got the bright idea of complaining to the local FCC field office. Apparently he made such a noise that an FCC engineer showed up at the site to investigate the problem. As it turned out, none of the commercial installations were at fault, but in the course of the investigation, the FCC engineer found more than half a dozen rules violations on the part of the amateur installation—and promptly ordered it off the air. Eventually, it lost it's site and now is just a memory of past mistakes. Needless-to-say, the other services sharing the site were perturbed at what they considered an unwarranted FCC examination, and they complained to the site owner. While I cannot vouch for the authenticity of this story, it is one that has been going around in FM circles for years. Each time I hear it told, the location has changed drastically. However, it does illustrate what can happen when amateurs forget that they are amateurs, and try to place themselves in a position superior to other services. As an amateur living with the "big-boys," it is ever important to keep a low profile.

Another way to keep this profile low is to handle any complaints of interference that your system is causing to other site users. Again, the other user will consider you, the "amateur," as the cause—simply because you *are* an amateur system. It is best to drop everything if such a call comes, and make a bee-line for your control system and shut down for a moment. If the complainant is still on the phone, ask him to hold for a moment and drop the system out of operation. Do not tell him you are doing it, simply do it—and then ask if the problem has been eliminated. If so, you have made a lasting positive impression on him and, if not, you have cleared your system as being the cause. Either way, your reaction should be prompt and helpful. You can make a lot of friends that way. If your system was the cause—or at least it looks as if it was—try bringing it back up while the complainant is on the phone. If the interference re-appears, shut down immediately, and keep it off till you can get to the site with the proper equipment to determine the cause. Stay off the air till you know the problem is solved and, if possible, make all final checks with the help of a spectrum analyzer. Commercial services, especially those concerned with public safety, will tolerate no interference whatsoever with their communications. Why take the risk of making enemies or receiving a citation from the FCC? No amateur operation is so important that it takes precedence over any service. We are, in most cases, a secondary service; they know it and we had best realize it. Learn to estimate your range, too (Table 8-2).

If all this seems a bit unfair to the amateur, you are right. Unfair, yes, but a way of life that amateurs who intend to involve themselves in repeater communications had best get accustomed to from the beginning. Except to other amateurs, our relay operations mean very little, and we are merely tolerated—nothing else.

There are other little factors that go into keeping a site-owner happy. When he is showing off the site to other prospective clients, it's nice if the location looks clean and sharp. Therefore, to some site owners, equipment appearance is important. Clip-leads are fine for work benches only: Keep them there. Have an installation that you are proud to look at, and others will find it pleasing to the eye as well. Remember, those coming to the site will be professionals, and they want things to look professional. Along these same lines, if you do any work on your system, be sure to clean up when you are finished. Nothing turns off a site owner more than visiting his property and finding wire scraps and defunct components scattered about. It takes

Table 8-2. A Radio-Range estimator chart (courtesy of Helper Instrument Co.).



1. *Locate your base station antenna height on your correct transmitter power vertical column.*
2. *Find the horizontal line closest to that point.*
3. *Step up one line for each dB of base station antenna gain and each dB of mobile antenna gain. Step down 1 line for each dB of base station coax line loss and each dB of mobile coax line loss.*
4. *Move across to the intersection of this line and the correct vertical frequency band. The intersection is the mileage range estimate for a 1 microvolt received signal. To find the .5 microvolt range, go up 6 lines (dB's).*

BEWARE: Range estimators are nothing more than estimators. They cannot account for local conditions and terrain variations. You can improve the reliability of your estimates by comparing the results with known systems in your area. Then determine what decibel corrections are needed to match these known systems and use, the corrections in your future estimates.

very little effort to clean up after you complete a repair, and the guy who owns the place will be appreciative.

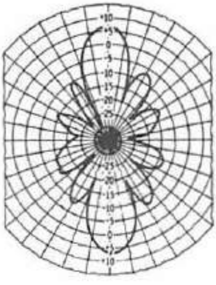
The fact is, you might even carry this a bit further. Site owners appreciate tenants who care about the property. It might help to show your appreciation by not only following the regulations he sets down, but carrying things a step further and offering to look after the site and perform minor maintenance to it. Perhaps you can strike some deal for reduced rent in exchange for performing such a service. Don't count on getting the reduction if you make such an offer; just do it to show good faith and it can go a long way.

There is still one more way you can be of help. If you notice people hanging around the site especially if it is in a remote area and unattended, try to contact the owner or some other authority, and report it promptly. *Under no circumstances play policeman*. Simply contact others more adept at such matters and let them handle it. By doing so, you are not only protecting the site from possible vandalism or theft, but protecting your own equipment as well. Everyone, except perhaps those being reported, will appreciate it. Also, don't be too surprised if you get this treatment the first few times you show up! Don't resent it—in the long run, it's protecting you and your system as well. Once people start to recognize your presence at the location, the reports will stop. Be thankful that others care, and have the same attitude yourself.

Yes, obtaining and keeping a good relay-system site is a one-sided game stacked against you. From this, you might get the feeling that any long-term amateur survival at commercial sites is impossible. Far from it! The majority of today's amateur systems use such accommodations, and have from the very beginning of the repeater concept. The ones that survive keep their profile low and abide by the regulations as set forth by the property owner. It's simply a matter of understanding that, when it comes to commercial-radio sites, amateur radio must take a back seat to everything else. In cases where your system is a guest at someone's home, or other building, all this is even more important. The following list applies to all sites and all operations:

- Obey any regulations regarding use of your site.
- Never take sightseers to "show off the machine." Many site owners frown on this practice.
- Never touch or tamper with in any way other equipment or installations at the site. Curiosity is fine, however, such acts are improper and illegal.
- Pay rent promptly. An easy way to loose a rental site is to forget to pay for it.
- Carry enough insurance to cover any eventuality. Payment of costs for damage caused by malfunction of your equipment could financially devastate you.
- Limit site-accessibility strictly to those in your group who are directly responsible for system maintenance.
- If you notice anything strange, such as people who do not belong at or around the site, loitering, or vandalism of any sort, notify the site owner immediately.
- Keep your installation neat, clean, and as unobstrusive as possible.
- Never complain directly to another system sharing the site, especially one which is non-amateur. Use technical skill to overcome your problem if possible. If a complaint must be filed, do so through the site owner. Remember—at any site, an amateur installation is considered secondary to other services.
- Handle any complaints lodged against your system by other services immediately. Failure to do so can lead to loss of site, or other consequences.

- Offer assistance to the site owner in overall site maintenance. This act of good faith can help ensure your longevity at the location.
- No matter what rate you pay, even if it is the full commercial rate, remember that as an amateur installation you are "the outsider." Most other services will wish you did not share the site with them. Therefore, always portray the best possible image when dealing with other site users and the site owner. Never argue, and always be flexible, no matter how unfair something may seem to you. Consider it lucky you have the site at all.



Chapter 9
Repeater Coordination

Why coordinate a repeater before putting it on the air? Doesn't the FCC Regulations give any amateur holding a Technician class or higher license the right to place a repeater on the air within the confines of the repeater sub-bands? (Except for 10 meters, where a General class or higher license is needed.) Can't I just put my repeater on the air when and where I want?

If you go strictly by the terms of the current rules and regulations, yes, you can. That is, if you do not care what the rest of the Amateurs in your area think of you. It's also fine if there are few, if any, other repeaters already operating in your area: However, if there are others operating, and if there is some established guideline regarding the installation of new repeater systems, you have a definite moral obligation to seek the advice and direction of your local coordinator or coordination body. Coordination means being a good neighbor—and herein lies a bit of FM nostalgia.

The first attempts at voluntary coordination was by individual amateurs who took the iniative to do such a job—unassisted, in most cases. People like Neil McKie, WA6KLA, who, in the late 1960's became southern California's first UHF (450 MHz) coordinator; and like his 2-meter counterpart, Jack Bankston, WA6JXG. As Neil tells it, someone had to do the job, and since they knew most of what was going on anyway, they just began to let the respective users of those bands know that someone had taken on the job. That was in 1966.

There were no nationally accepted bandplans in those days. It was simply a matter of locating a pair of frequencies which were not in use, and putting up your system. That was fine when there were not very many systems. However, things don't stand still, and in short order, more and more people were discovering FM and its associated repeaters. Repeaters began to step on one another's toes. Since no one knew what was in the mind of others, it was not surprising that, in some instances, more than one system might set up shop on the same channel pair, or wind up with a common input or output channel. That's why people like Neil, Jack, and others throughout the nation, took on the task of separating the systems, and trying to bring order from chaos. Before certain area's became overpopulated with FM relay devices, this individual-coordinator scheme worked fine. In many area's where FM activity is low, it still suffices. However, as more systems came into being, a new need developed: a dual need of tighter technical standards and political representation for a new group within the amateur community—the repeater owner/operator. Enter the repeater council.

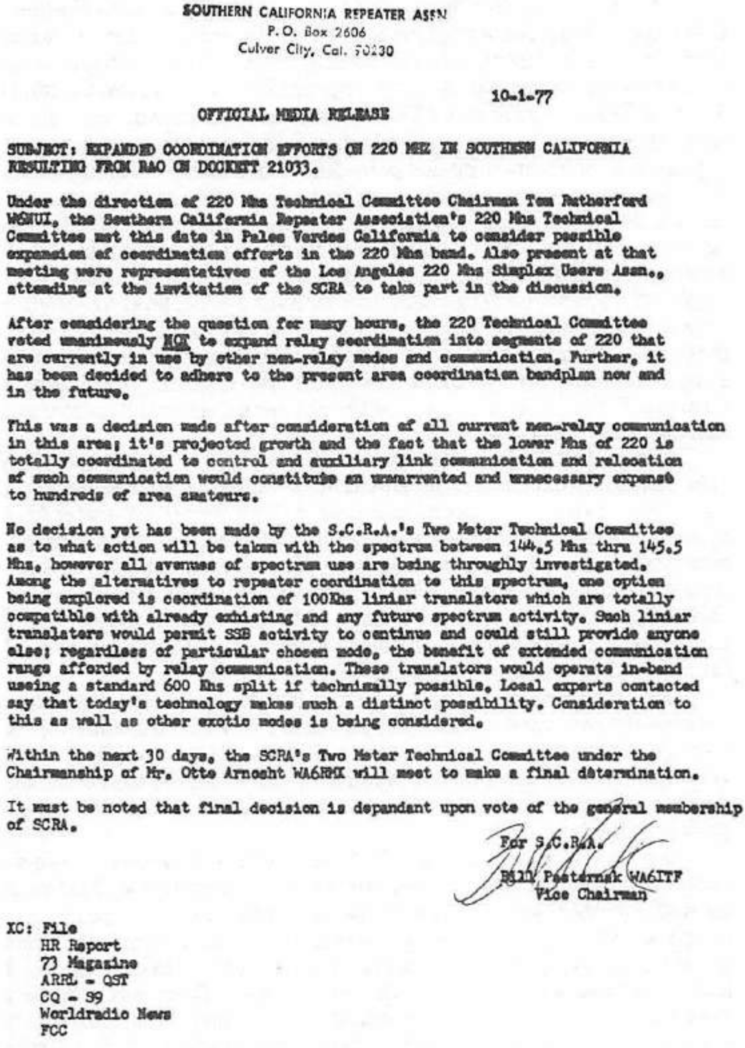
What records I have been able to locate seem to point to Northern California as being the birthplace of the repeater coordination council in 1966. As a result of tremendous repeater growth, and a need to give voice to the repeater owner/operator, an organization known as the California Amateur Relay Council; or CARC as it later became known, was born to serve those needs. Again, as to whether CARC was the very first such organization, or if something else precedes it is at this date unknown to me. What is known is that CARC was the basic model used by amateurs nationwide to form similar organizations of their own. From its birth to its demise in mid-1978, CARC accomplished much, and set trends that are still with us today. Before it passed out of existence, it gave birth to three other organizations, who, on a regional, rather than state-wide, level could better administer the affairs of the given areas. In fact, it was in giving birth to these new organizations that the need for CARC disappeared, and in its place have come the Northern Amateur Relay Council, The Southern California Repeater Association, and the Southern California Repeater and Remote Base Association.

In late 1978, another concept was born—that of overall spectrum management. From the then seven-year-old-Southern California Repeater Association, two new organizations emerged. They were the 2-meter Area Spectrum Management Association and the 220 MHz Spectrum Management Association of Southern California. These organizations were designed to represent every interested amateur regardless of mode preference. While, as I write this book in early 1979, this concept has just begun to take root here in California, amateurs in other areas have seen the need for this kind of organization and are beginning to copy it.

Let's stop for a moment, and look at the difference in the structure between the two types of organizations, and see why a need has developed. I will use for my example the now-defunct SCRA and the organization that grew from it, TASMA. I do this because of having served with both, and thereby being quite familiar with the original structure as well as the present scheme of things.

Repeater Councils such as SCRA were formed by repeater owner/operators for but one basic reason: To protect the interest of such individuals within amateur society. As more people wanted to put a repeater into operation, it became clear that some way had to be found to guide spectrum growth or chaos would result. See Figs. 9-1 through 9-3. In some places, it had already reached such a state, this area included. There was in the air a call for some sort of national standardization that would permit amateurs in one area to go to another area and be able to use his radio. In the late 1960's a bandplan was developed by amateurs in Texas, and their peers in other areas quickly recognized the value of such a plan and began to implement it. Eventually becoming known as the Modified Texas Plan, it placed repeaters 30 kHz from one another with input low/output high in the 146 to 147-MHz spectrum, and input high/output low in the 147 to 148-MHz spectrum. Input to output separation was, and still is 600 kHz.

By 1972, Southern California was deeply into the repeater way of life. However, there was no standardization, and input-to-output separation could be almost anywhere. Before Docket 18803, which was the first attempt by the FCC to regulate repeater operation, repeaters in this area used almost any combination from 144 to 148 MHz. Then 18803 forced all



SOUTHERN CALIFORNIA REPEATER ASSN
P.O. Box 2606
Culver City, Cal. 90230

10-1-77

OFFICIAL MEDIA RELEASE

SUBJECT: EXPANDED COORDINATION EFFORTS ON 220 MHZ IN SOUTHERN CALIFORNIA RESULTING FROM RAO ON DOCKETT 21033.

Under the direction of 220 Mhz Technical Committee Chairman Tom Rutherford W6NUI, the Southern California Repeater Association's 220 Mhz Technical Committee met this date in Palos Verdes California to consider possible expansion of coordination efforts in the 220 Mhz band. Also present at that meeting were representatives of the Los Angeles 220 Mhz Simplex Users Assn., attending at the invitation of the SCRA to take part in the discussion.

After considering the question for many hours, the 220 Technical Committee voted unanimously NOT to expand relay coordination into segments of 220 that are currently in use by other non-relay modes and communication. Further, it has been decided to adhere to the present area coordination bandplan now and in the future.

This was a decision made after consideration of all current non-relay communication in this area; it's projected growth and the fact that the lower Mhz of 220 is totally coordinated to control and auxiliary link communication and relocation of such communication would constitute an unwarranted and unnecessary expense to hundreds of area amateurs.

No decision yet has been made by the S.C.R.A.'s Two Meter Technical Committee as to what action will be taken with the spectrum between 144.5 Mhz thru 145.5 Mhz, however all avenues of spectrum use are being throughly investigated. Among the alternatives to repeater coordination to this spectrum, one option being explored is coordination of 100Khz liniar translators which are totally compatible with already exhisting and any future spectrum activity. Such liniar translaters would permit SSB activity to continue and could still provide anyone else; regardless of particular chosen mode, the benefit of extended communication range afforded by relay communication. These translators would operate in-band useing a standard 600 Khz split if technically possible. Local experts contacted say that today's technology makes such a distinct possibility. Consideration to this as well as other exotic modes is being considered.

Within the next 30 days, the SCRA's Two Meter Technical Committee under the Chairmanship of Mr. Otto Arnoeht WA6RMX will meet to make a final determination.

It must be noted that final decision is dependant upon vote of the general membership of SCRA.

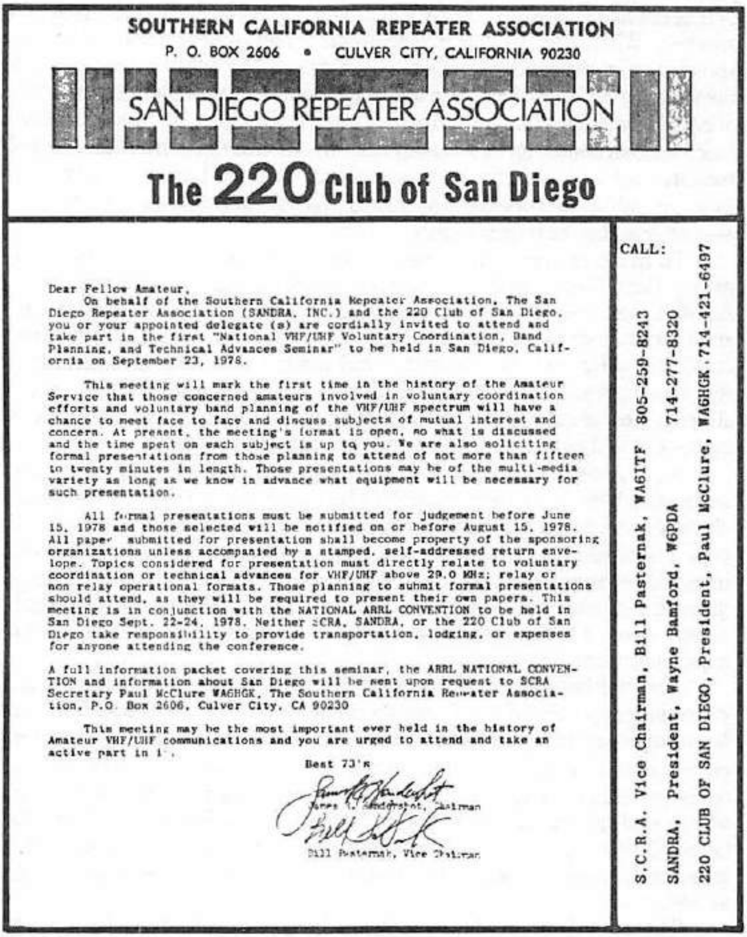
For S.C.R.A.
Bill Pasternak WA6ITF
Vice Chairman

XC: File
HR Report
73 Magazine
ARRL - QST
CQ - 59
Worldradio News
FCC

Fig. 9-1. Typical press release sent out by repeater council.

relay activity into the upper two MHz, and it was crowded. It was to find everyone a home, to assure that this area would conform to the rest of the nation and to give those involved in relay activity a political voice in spectrum development that, in 1972, amateurs from all over southern California met and formed the Southern California Repeater Association.

Like other organizations of similar structure, voting in all matters brought before the council was limited to amateurs who were SCRA members, and who owned SCRA-coordinated repeaters. Under this structure, one still prevalent on a national level today, repeater councils represent the view of the repeater owner/operator, and any voice that repeater users and other spectrum inhabitants have must be presented through a repeater owner. There is absolutely nothing wrong with this arrangement as long as the majority of an area's amateurs want it that way. In most cases, they do, and repeater councils operating under such a structure abound. Most, if not all, offer "Associate," non-voting membership to any interested amateur, which permits participation in all discussions. However, it's the man who owns the repeater who has the votes. It was under such an organizational structure as this that SCRA prospered for seven and a half years. In its time it witnessed phenomenal growth in repeater activity on both 2-meters and 220 MHz—the bands that it was empowered to



SOUTHERN CALIFORNIA REPEATER ASSOCIATION
P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

SAN DIEGO REPEATER ASSOCIATION

The 220 Club of San Diego

Dear Fellow Amateur,

On behalf of the Southern California Repeater Association, The San Diego Repeater Association (SANDRA, INC.) and the 220 Club of San Diego, you or your appointed delegate (s) are cordially invited to attend and take part in the first "National VHF/UHF Voluntary Coordination, Band Planning, and Technical Advances Seminar" to be held in San Diego, California on September 23, 1978.

This meeting will mark the first time in the history of the Amateur Service that those concerned amateurs involved in voluntary coordination efforts and voluntary band planning of the VHF/UHF spectrum will have a chance to meet face to face and discuss subjects of mutual interest and concern. At present, the meeting's format is open, so what is discussed and the time spent on each subject is up to you. We are also soliciting formal presentations from those planning to attend of not more than fifteen to twenty minutes in length. Those presentations may be of the multi-media variety as long as we know in advance what equipment will be necessary for such presentation.

All formal presentations must be submitted for judgement before June 15, 1978 and those selected will be notified on or before August 15, 1978. All paper submitted for presentation shall become property of the sponsoring organizations unless accompanied by a stamped, self-addressed return envelope. Topics considered for presentation must directly relate to voluntary coordination or technical advances for VHF/UHF above 29.0 MHz; relay or non relay operational formats. Those planning to submit formal presentations should attend, as they will be required to present their own papers. This meeting is in conjunction with the NATIONAL ARRL CONVENTION to be held in San Diego Sept. 22-24, 1978. Neither SCRA, SANDRA, or the 220 Club of San Diego take responsibility to provide transportation, lodging, or expenses for anyone attending the conference.

A full information packet covering this seminar, the ARRL NATIONAL CONVENTION and information about San Diego will be sent upon request to SCRA Secretary Paul McClure WA6HGK, The Southern California Repeater Association, P.O. Box 2606, Culver City, CA 90230

This meeting may be the most important ever held in the history of Amateur VHF/UHF communications and you are urged to attend and take an active part in it.

Best 73's

James T. Hendershot, Chairman

Bill Pasternak, Vice Chairman

CALL:

S.C.R.A. Vice Chairman, Bill Pasternak, WA6ITF 805-259-8243

SANDRA, President, Wayne Bamford, W6PDA 714-277-8320

220 CLUB OF SAN DIEGO, President, Paul McClure, WA6HGK, 714-421-6497

Fig. 9-2. Another repeater council job is education. This letter started the biggest such meeting ever held in the west.

administer under area-wide agreement. Under SCRA some 200 repeaters came to 2-meters, and close to another 100 came to life on 220 MHz. It had two technical committees—one for each band—which handled the matters of finding homes for new repeaters and setting technical-operating standards. It also was responsible for another milestone: originating a modification of the Texas plan to permit doubling the number of available repeater pairs by halving the separation between systems, but doing so in a way that caused minimal impact to existing systems.

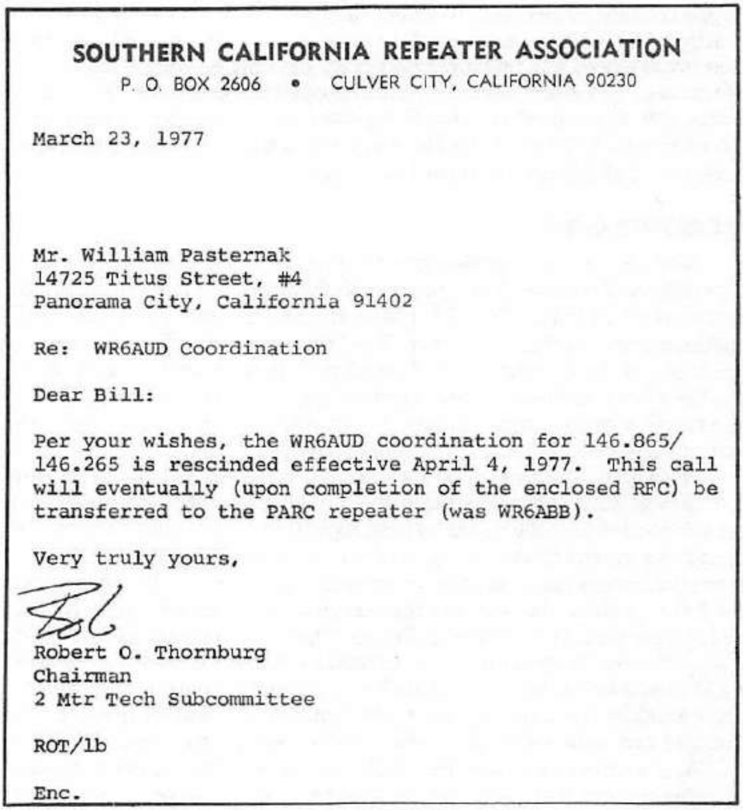
In 1973, Southern California found itself without any place to put another repeater without causing harm to existing activity. SCRA had watched other attempts at reducing the spacing between repeaters, and had seen some disastrous results. In many cases, users were forced to purchase new radio's or modify existing ones, because the majority of rigs of that era had problems in separating two repeaters only 15 kHz from one another. With over 10,000 people using 2-meter repeaters, and more showing up on the band every day, SCRA was under pressure not to disturb the status-quo. They were also under pressure from another quarter: that of people awaiting a home for the new box they had just completed. If they could not find homes for these systems it would mean a return to the days of repeater wars wherein the strongest signal from the highest mountaintop wins out. What they needed was a King Solomon and—as luck would have it—not one, but two came forth.

To those of you in the broadcast or communications industries, the names Burt Weiner and Bob Thornburg will probably ring a bell. Burt, K6OQK, and Bob, WB6JPI, are well-known and respected in those fields, and it was from them that came the simple idea of inverting the newly created 15-kHz tertiary channels—thus placing repeater outputs next to repeater inputs. The rationale was simple: The usually superior equipment at a repeater, along with the higher overall technical ability of most repeater owners, could better cope with adjacent-channel problems.

To the user, it meant that his radio would always see a 30-kHz separation between repeaters, unless he was in the vicinity of an adjacent-channel system 15 kHz away. Even then, the stronger signal from the repeater would overcome this one slight problem—in most cases. This inverted tertiary system was also based upon the fact that, in most cases, users are in lower places than repeaters, and are mobile most of the time. In severe cases it became simply a matter of driving away from the source of adjacent-channel interference.

The plan became known as the SCRA Inverted Tertiary Bandplan, and eventually superceded the Texas plan in most parts of the nation. It has not been implemented nationally because, in some areas a heavy monetary committment had been made to systems and users using the right-side-up tertiary-channel allocations. This is true particularly in the Northeast, where such a committment existed long before SCRA brought forth the inverted tertiary bandplan. However, as older crystal-controlled radios give way to newer synthesized ones, this picture could eventually change as well.

These, and other, decisions were being made by repeater owners without the consent of any other spectrum users. While such decisions were usually designed to protect the repeater user, and other spectrum



SOUTHERN CALIFORNIA REPEATER ASSOCIATION
P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

March 23, 1977

Mr. William Pasternak
14725 Titus Street, #4
Panorama City, California 91402

Re: WR6AUD Coordination

Dear Bill:

Per your wishes, the WR6AUD coordination for 146.865/146.265 is rescinded effective April 4, 1977. This call will eventually (upon completion of the enclosed RFC) be transferred to the PARC repeater (was WR6ABB).

Very truly yours,

Robert O. Thornburg
Chairman
2 Mtr Tech Subcommittee

ROT/lb

Enc.

Fig. 9-3. Typical letter of change in coordination status.

dwellers as well, nonetheless, if you did not own a repeater you had no say in matters that concerned every aspect of your day-to-day amateur operation. This eventually led to resentment in some quarters, and a new slogan was soon to be heard: User Rights! The people who used the band and the repeaters began to demand a direct voice in all matters.

The first of many attempts to open voting membership to non-repeater-owners came in the spring of 1976—our nations Bi-centennial year, in the form of a motion brought before the membership by Bob Thornburg, WB6JPI. Though he presented a rational case for such a move, the motion was defeated, based upon the concept that SCRA was a repeater-owners organization and, as such, its voting membership must be limited to those who own and operate repeaters. In the years that followed, the motion was brought up again and again—each time going down to defeat. Then, in 1978, a number of events took place that would change all this.

By 1978 many of what I will term the "old guard," those who had been around from the birth of SCRA and prior to it, those who had pioneered the first generation of repeaters had tired of political involvement and had stopped coming to meetings. Whether they were "burned out" from years of activity, or simply convinced that things were pretty well set and that their involvement was no longer necessary can only be speculated on. In either case, "old guard" attendance had dropped markedly over the years. It was now the second generation repeater owner in control—many involved with both 220 and 144 MHz. They were a far more liberal group, and were not at all adamant in regard to change.

THE GROWTH IN VHF

Next, there was a sudden growth in modes other than FM on VHF, especially on 2 meters. A number of manufacturers had introduced radios that worked on SSB, CW, AM, FM, and FSK, thereby giving the VHF enthusiast new worlds to conquer. The "Multi-Mode" radio had changed the scope of things completely. A budding SSB-enthusiast's organization had been formed, called Southern California Sidewinders on Two, and tied to its mother organization in Dallas, Texas. SSB activity was growing at an almost unprecedented rate, with most activity centered near 145 MHz.

This was all well and good until the FCC released what is still termed the "deregulation bombshell, through it, creating a second 2-meter repeater sub-band right in the middle of existing SSB activity. Again, there was a chance for confrontation among amateurs; this time, an inter-mode confrontation. Some experiments soon showed that it would be the FMers and the FM repeaters who would be the certain losers of such a confrontation, and that such must be avoided at all costs. This was before the FCC revised it's position and opened the 22-meter band from 144.1 to 148 MHz for use by Technician-class operators, allowing them to move lower in spectrum to accommodate the new repeaters. At that time, it was obvious that a dialogue had to be developed between all other spectrum users and the SCRA, if whatever was to come would lead to peaceful transition. Such a dialogue was initiated—a dialogue that was to play a great part in what was to transpire over the next few months and eventually lead to the birth of this nation's first two voluntary overall-spectrum-management organizations.

With most of the organization's attention centered again on 2 meters, 220 MHz was left lacking by all those other than the 220 Technical Committee. Yet this band was growing at a rate similar to that of 2 meters. It was having growth pains, yes, but those guiding it had learned from prior mistakes and were being quite careful. However, by mid 1978 it was apparent that 220 needed its own separate organization to represent the needs of its users. From the outset, the planners of the new 220 group made it clear that they were going a step beyond the repeater-council concept, and would offer voting membership to any licensed amateur who wished to help in guiding the orderly growth of 220. The inhabitants of that band were very eager to become part of such a structure, and this made the 2-meter leaders wonder if now was not the right time to implement a similar structure for that band as well.

In the summer of 1978, at a meeting at Cerretos College in Norwalk, California, two important events transpired. By vote of the SCRA membership present, it was decided to split the organization into two new structures; one each for 2 meters and 220 MHz, and further, to implement a new structure within the SCRA in relation to 2-meter matters. In essence, an almost carbon copy of the new 220 organization, with open voting membership available to any interested licensed amateur. Now everyone had a voice. The only question was, could it work.

Immediately, both organizations went to work. Since I have served with the 2-meter group I will dwell upon it. However, the 220 organization has taken similar steps and met with similar success. A band plan was needed to insure the sanctity of all operators and all modes of operation. Luckily, the ARRL's VHF Repeater Advisory Committee had just released a truly workable one. The SCRA—under its new title of Two Meter Area Spectrum Management Association—took it under advisement, made some slight changes to it, brought it before the membership where it received unanimous approval, and began its area-wide implementation. To their up-to-then repeater-owner-only technical committee were added representatives of other modes and interests so as to give those interests a direct voice. It gave formal recognition and coordinated band-space to such new entities as linear translators for repeating SSB, and single-frequency "Simplex Autopatch Systems." Most important, due to its open attitude, it's ranks of supporters have swelled. It has proved that there is no reason to fear your fellow amateur, and that through mutual cooperation all can prosper.

Months have transpired since TASMA and 220-SMA were formed. Both organizations still coordinate repeaters, but they also serve the needs of this area's Amateurs in many other ways. I suspect that they are the forerunners of many similar organizations to come.

THE PROCEDURE FROM BEGINNING TO END

Thus far we have discussed the different technical/political structures found in voluntary coordination. It is now time to look at the diverse ways in which repeater coordination takes place. There are many, but we will discuss only three: individual, committee, and "advise and consent." All others are either offshoots or variations on one of these themes.

The individual who functions as area repeater coordinator has the hardest job of any of the three designations. He is one individual who must make technically competent decisions about the best "spot" for any new system, and is also forced—due to lack of a formal organizational support—to act as that area's political voice for its repeater owners. Thus he has a dual role, and it takes a super human to keep going under such conditions—especially when one considers that what he does is on a volunteer basis.

The tools of the coordinator are area technical standards, limitations as set forth in the FCC Rules and Regulations pertaining to amateur relay devices, a thorough knowledge of area terrain, the location of existing activity, a good set of topographical relief maps, a telephone, an ability to reason with people, and—for some—a bottle of aspirin.

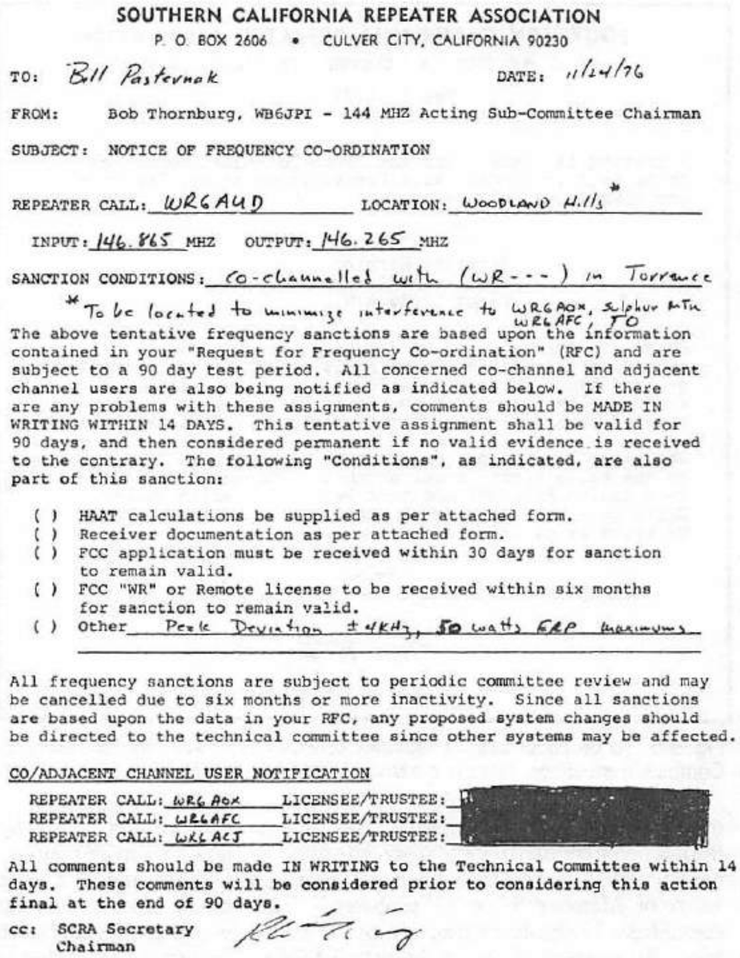
Luckily, most individual coordinators these days serve sparsly populated areas. Those who operate in densly populated areas are usually part of some regional-coordination body which has elected to use individual talent, though with the technical and political support of their organization. For the moment, however, let's concentrate on the individual without such support. Usually, the first step in obtaining coordination for your proposed system is to find the person doing the job. Perhaps the easiest way to do this is by obtaining a current ARRL repeater directory. The ARRL lists all area coordinators and councils, and it's a sure bet that your coordinator will be listed. In lieu of this, try asking other Amateurs in your area, especially established repeater owners. They are bound to send you in the proper direction since, more likely than not, they have dealt with him at one time or another.

Most likely, a note or phone call to him will produce a set of Coordination Request Forms in short order, see Fig. 10-1, most, if not all, coordinators and/or coordination councils use a similar form to gather the information with which to make a technically competent determination in your case. The forms usually ask for a detailed description of your intended system, the location you have chosen as a site for it, and what you project its coverage to be. You complete these forms and mail them back. Now the real work begins.

From the information you have supplied, the coordinator must make a judgement as to what he feels is the best place for you to fit in with already existing activity. Just because the area he administers has no operational machine on a given channel pair is not enough justification for him to assign it to you. The adjoining area may already have a system on that channel pair, and, while you might not hear it, your proposed new repeater might be going into a site that could cause severe interference. Such has happened in the past, and a smart coordinator takes this into consideration when evaluating your request. Another factor is the location of the users. True, your proposed system might not cause harm to a co-channel system, but some of those who will be your users might be in an area that would cause them to key up both your machine and another they did not intend to use. In the end, his decision on a spot for you will be based upon many factors. If he uses poor judgement and makes an unwise choice, he will cause harm not only to you but to others as well. Therefore, most coordinators tend to be conservative in their decisions, and may impose certain restrictions on your system—restrictions he deems to be in the welfare of all spectrum users. Such restrictions may take the form of power limitations, specific antenna patterns to direct your systems signal to a specific area, or limited access to your system through tone access—even for open-category repeaters, in some cases. These restrictions may not be popular with you or your users but they are imposed in the interest of the overall amateur community, and are best adhered to from the start.

When he has made his decision the coordinator will usually send you a letter of authorization to begin testing your repeater on a specific set of channels for a specified time. This letter is call a "Sanction" and is your "permit" from the amateurs of your area to try out your new system.

There is nothing legally binding—nothing that will stand up in a court of law—which stipulates that you must adhere to the decision of a coordinator. The bond is moral only, but it is one that most amateurs involved in relay communications respect and adhere to without question. I suspect that this is because most amateurs intending to place a repeater into operation—especially an open one—are doing so in the interest of serving their local community and as thus want the support of that area's amateurs. To have a repeater that has no support, and thus no users is a waste of time and



SOUTHERN CALIFORNIA REPEATER ASSOCIATION
P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

TO: Bill Pasternak DATE: 11/24/76

FROM: Bob Thornburg, WB6JPI - 144 MHZ Acting Sub-Committee Chairman

SUBJECT: NOTICE OF FREQUENCY CO-ORDINATION

REPEATER CALL: WR6AUD LOCATION: Woodland Hills*

INPUT: 146.865 MHZ OUTPUT: 146.265 MHZ

SANCTION CONDITIONS: Co-channelled with (WR---) in Torrance

*To be located to minimize interference to WR6AOX, Sulphur Mtn WR6AFC, TO

The above tentative frequency sanctions are based upon the information contained in your "Request for Frequency Co-ordination" (RFC) and are subject to a 90 day test period. All concerned co-channel and adjacent channel users are also being notified as indicated below. If there are any problems with these assignments, comments should be MADE IN WRITING WITHIN 14 DAYS. This tentative assignment shall be valid for 90 days, and then considered permanent if no valid evidence is received to the contrary. The following "Conditions", as indicated, are also part of this sanction:

( ) HAAT calculations be supplied as per attached form.
( ) Receiver documentation as per attached form.
( ) FCC application must be received within 30 days for sanction to remain valid.
( ) FCC "WR" or Remote license to be received within six months for sanction to remain valid.
( ) Other Peak Deviation ±4KHz, 50 watts ERP maximums

All frequency sanctions are subject to periodic committee review and may be cancelled due to six months or more inactivity. Since all sanctions are based upon the data in your RFC, any proposed system changes should be directed to the technical committee since other systems may be affected.

CO/ADJACENT CHANNEL USER NOTIFICATION

REPEATER CALL: WR6AOX LICENSEE/TRUSTEE: [redacted]
REPEATER CALL: WR6AFC LICENSEE/TRUSTEE:
REPEATER CALL: WR6ACJ LICENSEE/TRUSTEE:

All comments should be made IN WRITING to the Technical Committee within 14 days. These comments will be considered prior to considering this action final at the end of 90 days.

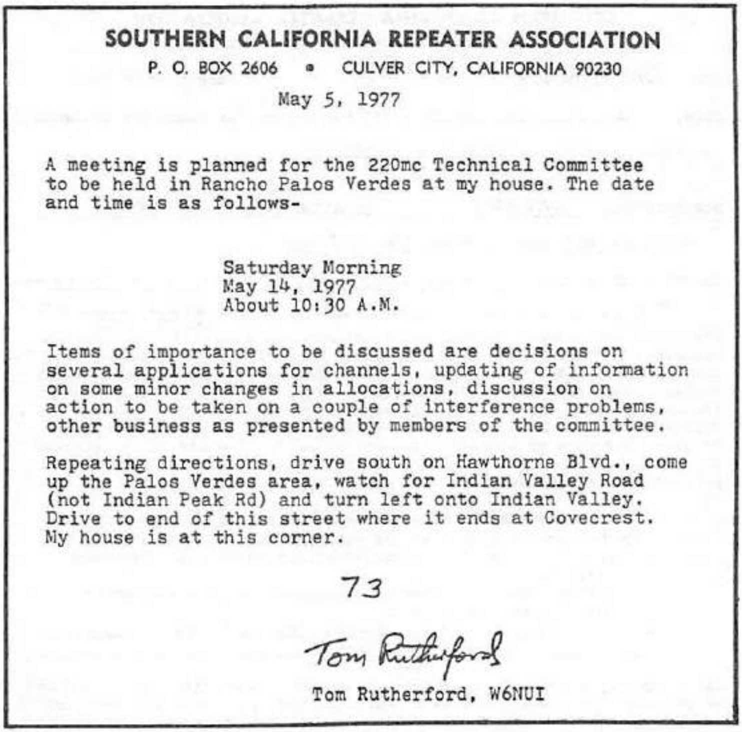
cc: SCRA Secretary
Chairman

Fig. 9-4. Sample letter of sanction sent to prospective repeater owner.

money. Now and then an owner places personal ego satisfaction above the welfare of the rest of the amateur community, and does as he or she pleases. Systems coming into operation in this manner are uncoordinated, and have become known as "Pirate Repeaters." It's interesting that most pirates do not last long, since, without support, they serve no purpose. They find few, if any, users and eventually just "sort of disappear." To date, ignoring the very existence of pirates has been amateur radio's best weapon.

THE TECHNICAL COMMITTEE

Another method of coordination used mainly by repeater councils, is that of coordination by Technical Committee. Here a body of regional



SOUTHERN CALIFORNIA REPEATER ASSOCIATION
P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

May 5, 1977

A meeting is planned for the 220mc Technical Committee to be held in Rancho Palos Verdes at my house. The date and time is as follows-

Saturday Morning
May 14, 1977
About 10:30 A.M.

Items of importance to be discussed are decisions on several applications for channels, updating of information on some minor changes in allocations, discussion on action to be taken on a couple of interference problems, other business as presented by members of the committee.

Repeating directions, drive south on Hawthorne Blvd., come up the Palos Verdes area, watch for Indian Valley Road (not Indian Peak Rd) and turn left onto Indian Valley. Drive to end of this street where it ends at Covecrest. My house is at this corner.

73

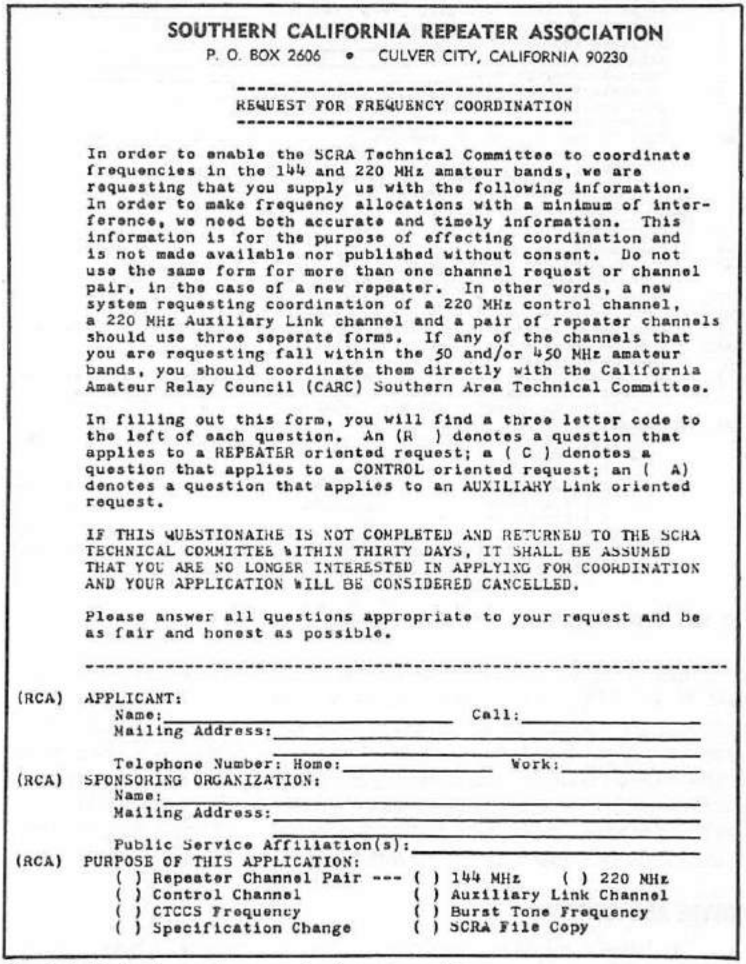
Tom Rutherford

Tom Rutherford, W6NUI

Fig. 9-5. To be successful, a repeater council must have regular Technical Committee meetings. Here is a sample of meeting notice.

experts share the load of decision. The same tools and criteria as used by the individual coordinator still apply, however, you now have more than one person versed on what is happening in the area, and what member "A" isn't aware of, Member"B" or "C" probably is. The makeup of such technical committees is usually such as to represent all areas of a given geographic zone. An example of this is the way TASMA's Technical Committee is structured. Those serving on it, and involved in the repeater coordination aspect of its work, must be well acquainted with all sides of Amateur relay operation, and thoroughly acquainted with all spectral activity in their locality. There is a minimum of one member each from the following areas: Santa Barbara and vicinity, Ventura County, Los Angeles County, San Diego County, Orange County, San Bernadino County, and Riverside County. If you were to consult a map of this region you would note that, with the exception of a line between Ventura through Los Angeles and Orange County to San Diego, all other areas have natural geographic boundaries separating them. Therefore, it is very hard for someone in Los Angeles to know exactly the activity in Barstow or Indio. For that reason, minds are brought together in committee to make a final determination based upon all known activity. In an area that now boasts close to 19,000 2-meter users, such a conclave of technical knowledge is essential. It has been through pooling the knowledge of many informed amateurs that has kept coordination attempts from becoming experiments in disaster.

There is another positive by-product of the committee approach; a political one. There have been cases where the individual coordinator has been accused of bias, or of showing favoritism. Rightfully or wrongfully, this has happened to coordinator after coordinator over the years. This is all but impossible under the committee structure outlined. There is little, if any, chance that a prospective repeater owner will personally know each of the members of a committee structured as just described. So, on a political level, the chance of conflict of interest is avoided. This is another definite plus for the Technical Committee approach, and is the reason that many Coordination Councils across the nation have adopted such a structure.



SOUTHERN CALIFORNIA REPEATER ASSOCIATION

P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

REQUEST FOR FREQUENCY COORDINATION

In order to enable the SCRA Technical Committee to coordinate frequencies in the 144 and 220 MHz amateur bands, we are requesting that you supply us with the following information. In order to make frequency allocations with a minimum of interference, we need both accurate and timely information. This information is for the purpose of effecting coordination and is not made available nor published without consent. Do not use the same form for more than one channel request or channel pair, in the case of a new repeater. In other words, a new system requesting coordination of a 220 MHz control channel, a 220 MHz Auxiliary Link channel and a pair of repeater channels should use three seperate forms. If any of the channels that you are requesting fall within the 50 and/or 450 MHz amateur bands, you should coordinate them directly with the California Amateur Relay Council (CARC) Southern Area Technical Committee.

In filling out this form, you will find a three letter code to the left of each question. An (R) denotes a question that applies to a REPEATER oriented request; a (C) denotes a question that applies to a CONTROL oriented request; an (A) denotes a question that applies to an AUXILIARY Link oriented request.

IF THIS QUESTIONAIRE IS NOT COMPLETED AND RETURNED TO THE SCRA TECHNICAL COMMITTEE WITHIN THIRTY DAYS, IT SHALL BE ASSUMED THAT YOU ARE NO LONGER INTERESTED IN APPLYING FOR COORDINATION AND YOUR APPLICATION WILL BE CONSIDERED CANCELLED.

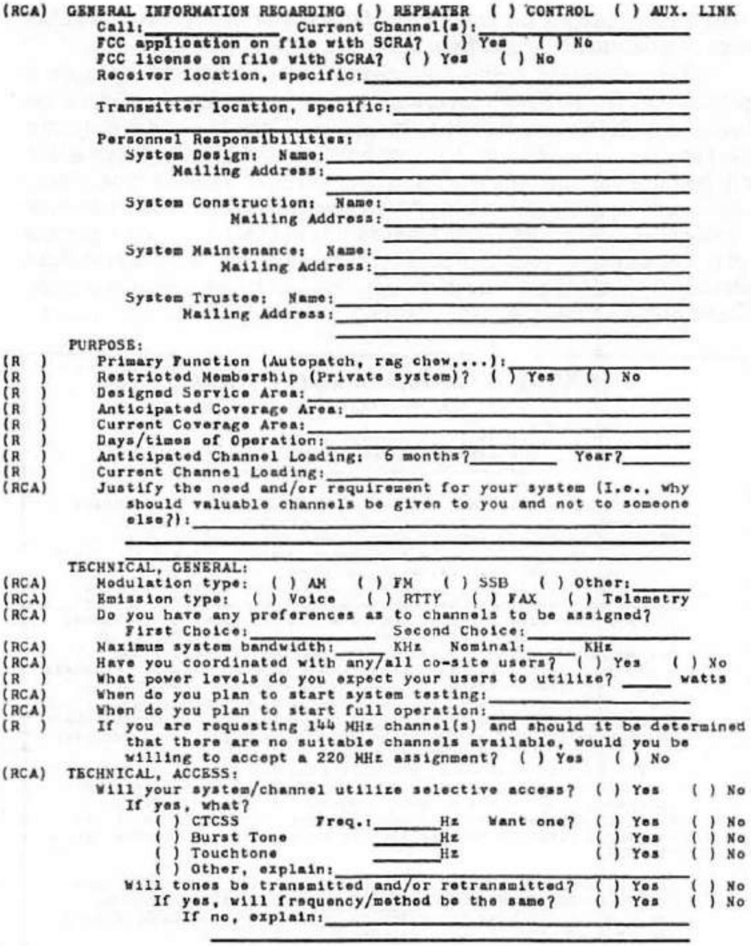
Please answer all questions appropriate to your request and be as fair and honest as possible.

(RCA) APPLICANT:
Name: ____________ Call: ________
Mailing Address: ____________
Telephone Number: Home: ________ Work: ________

(RCA) SPONSORING ORGANIZATION:
Name: ____________
Mailing Address: ____________
Public Service Affiliation(s): ____________

(RCA) PURPOSE OF THIS APPLICATION:
( ) Repeater Channel Pair --- ( ) 144 MHz ( ) 220 MHz
( ) Control Channel ( ) Auxiliary Link Channel
( ) CTCCS Frequency ( ) Burst Tone Frequency
( ) Specification Change ( ) SCRA File Copy

Fig. 9-6. Typical repeater coordination request form.



(RCA) GENERAL INFORMATION REGARDING ( ) REPEATER ( ) CONTROL ( ) AUX. LINK
Call: ____________ Current Channel(s): ____________
FCC application on file with SCRA? ( ) Yes ( ) No
FCC license on file with SCRA? ( ) Yes ( ) No
Receiver location, specific: ____________
Transmitter location, specific: ____________
Personnel Responsibilities:
System Design: Name: ____________
Mailing Address: ____________
System Construction: Name: ____________
Mailing Address: ____________
System Maintenance: Name: ____________
Mailing Address: ____________
System Trustee: Name: ____________
Mailing Address: ____________

PURPOSE:
(R) Primary Function (Autopatch, rag chew,...): ____________
(R) Restricted Membership (Private system)? ( ) Yes ( ) No
(R) Designed Service Area: ____________
(R) Anticipated Coverage Area: ____________
(R) Current Coverage Area: ____________
(R) Days/times of Operation: ____________
(R) Anticipated Channel Loading: 6 months? ________ Year? ________
(R) Current Channel Loading: ________
(RCA) Justify the need and/or requirement for your system (I.e., why should valuable channels be given to you and not to someone else?): ____________

TECHNICAL, GENERAL:
(RCA) Modulation type: ( ) AM ( ) FM ( ) SSB ( ) Other: ______
(RCA) Emission type: ( ) Voice ( ) RTTY ( ) FAX ( ) Telemetry
(RCA) Do you have any preferences as to channels to be assigned?
First Choice: ____________ Second Choice: ____________
(RCA) Maximum system bandwidth: ______ KHz Nominal: ______ KHz
(RCA) Have you coordinated with any/all co-site users? ( ) Yes ( ) No
(R) What power levels do you expect your users to utilize? ______ watts
(RCA) When do you plan to start system testing: ____________
(RCA) When do you plan to start full operation: ____________
(R) If you are requesting 144 MHz channel(s) and should it be determined that there are no suitable channels available, would you be willing to accept a 220 MHz assignment? ( ) Yes ( ) No
(RCA) TECHNICAL, ACCESS:
Will your system/channel utilize selective access? ( ) Yes ( ) No
If yes, what?
( ) CTCSS Freq.: ________ Hz Want one? ( ) Yes ( ) No
( ) Burst Tone ________ Hz ( ) Yes ( ) No
( ) Touchtone ________ Hz ( ) Yes ( ) No
( ) Other, explain: ____________
Will tones be transmitted and/or retransmitted? ( ) Yes ( ) No
If yes, will frequency/method be the same? ( ) Yes ( ) No
If no, explain: ____________

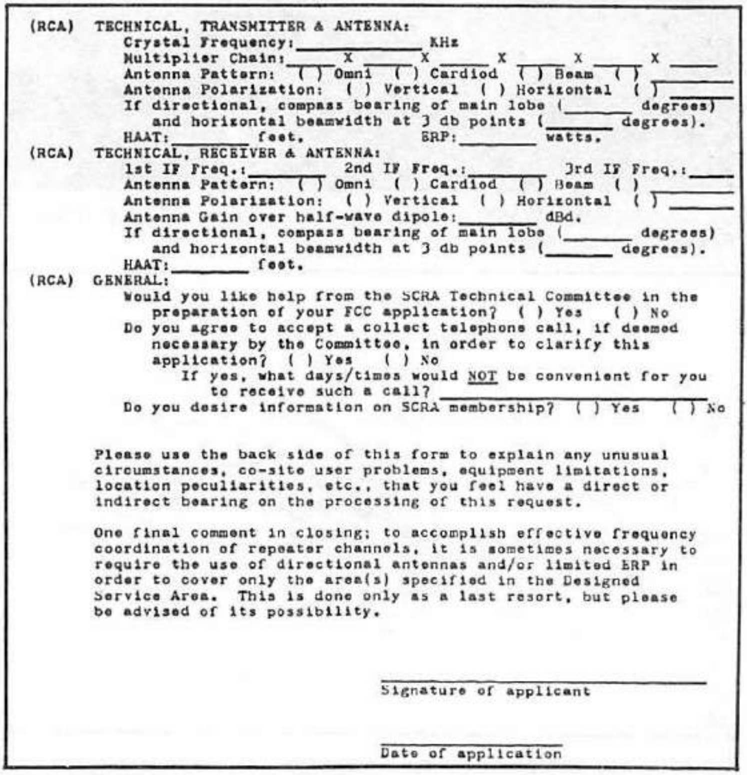
Fig. 9-7. Typical repeater coordination request form.

What other functions do such Technical Committee's perform? In the case of TASMA—when it was still SCRA—they developed area-wide standards for such things as deviation, tone access, signalling and dialing tones for autopatch use, and a whole lot more. A complete set of Southern California Area Wide Standards as they are today appears in the appendix of this book as an example of such standards. Another job they perform is the compiling of area activity data, so that the council itself can publish a listing of area activity. Most councils do this two to four times annually.

ADVISE AND CONSENT

The latest method of coordination to surface is what I have dubbed "Advise and Consent" coordination. It is a concept developed in 1977/78 by the Illinois Repeater Council, and is the only solution in cases where an area has totally run out of available spectrum. One might call it the "big-city coordinators last stand." It works this way: Instead of sending the prospective repeater owner just a coordination-request form, he is also sent a letter explaining the current crowded situation and suggesting alternatives. He is also told that if he wishes to proceed, he will have to do his own research and locate the frequency where he will cause minimal interference to existing activity and to himself. To facilitate this, he is sent an accurate listing of all known area activity. He is instructed to make his choice and, using the normal coordination-request form, to notify the council of his choice so as to facilitate public listing of his machine. See Figs. 9-4 through 9-10.

Under this system, the total responsibility for coordination and all research is placed upon the shoulders of the new owner. The rationale is that most amateurs will seek a home for their system which will insure its survival. They will look for a set of channels permitting minimal interference to themselves, thereby causing a minimal amount to those already there. Though there is always the possibility that, given this much latitude, someone will get the idea to wage war on someone else so as to obtain a



(RCA) TECHNICAL, TRANSMITTER & ANTENNA:
Crystal Frequency: ______________ KHz
Multiplier Chain: ______ X ______ X ______ X ______ X ______ X ______
Antenna Pattern: ( ) Omni ( ) Cardiod ( ) Beam ( ) ________
Antenna Polarization: ( ) Vertical ( ) Horizontal ( ) ________
If directional, compass bearing of main lobe (________ degrees)
and horizontal beamwidth at 3 db points (________ degrees).
HAAT: ________ feet. ERP: ________ watts.

(RCA) TECHNICAL, RECEIVER & ANTENNA:
1st IF Freq.: ________ 2nd IF Freq.: ________ 3rd IF Freq.: ____
Antenna Pattern: ( ) Omni ( ) Cardiod ( ) Beam ( ) ________
Antenna Polarization: ( ) Vertical ( ) Horizontal ( ) ________
Antenna Gain over half-wave dipole: ________ dBd.
If directional, compass bearing of main lobe (________ degrees)
and horizontal beamwidth at 3 db points (________ degrees).
HAAT: ________ feet.

(RCA) GENERAL:
Would you like help from the SCRA Technical Committee in the preparation of your FCC application? ( ) Yes ( ) No
Do you agree to accept a collect telephone call, if deemed necessary by the Committee, in order to clarify this application? ( ) Yes ( ) No
If yes, what days/times would NOT be convenient for you to receive such a call? ____________________
Do you desire information on SCRA membership? ( ) Yes ( ) No

Please use the back side of this form to explain any unusual circumstances, co-site user problems, equipment limitations, location peculiarities, etc., that you feel have a direct or indirect bearing on the processing of this request.

One final comment in closing; to accomplish effective frequency coordination of repeater channels, it is sometimes necessary to require the use of directional antennas and/or limited ERP in order to cover only the area(s) specified in the Designed Service Area. This is done only as a last resort, but please be advised of its possibility.

____
Signature of applicant

____
Date of application

Fig. 9-8. Typical repeater coordination request form.

Fig. 9-9. Neal McKie, WA6KLA, was an early FM pioneer and Southern California's first UHF coordinator.

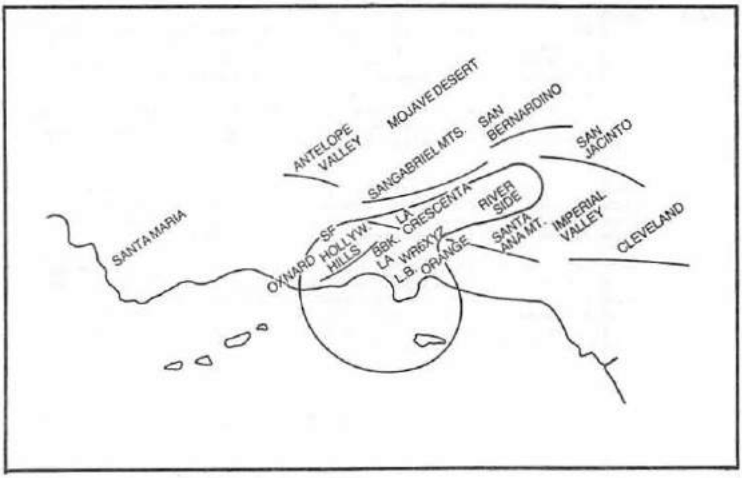
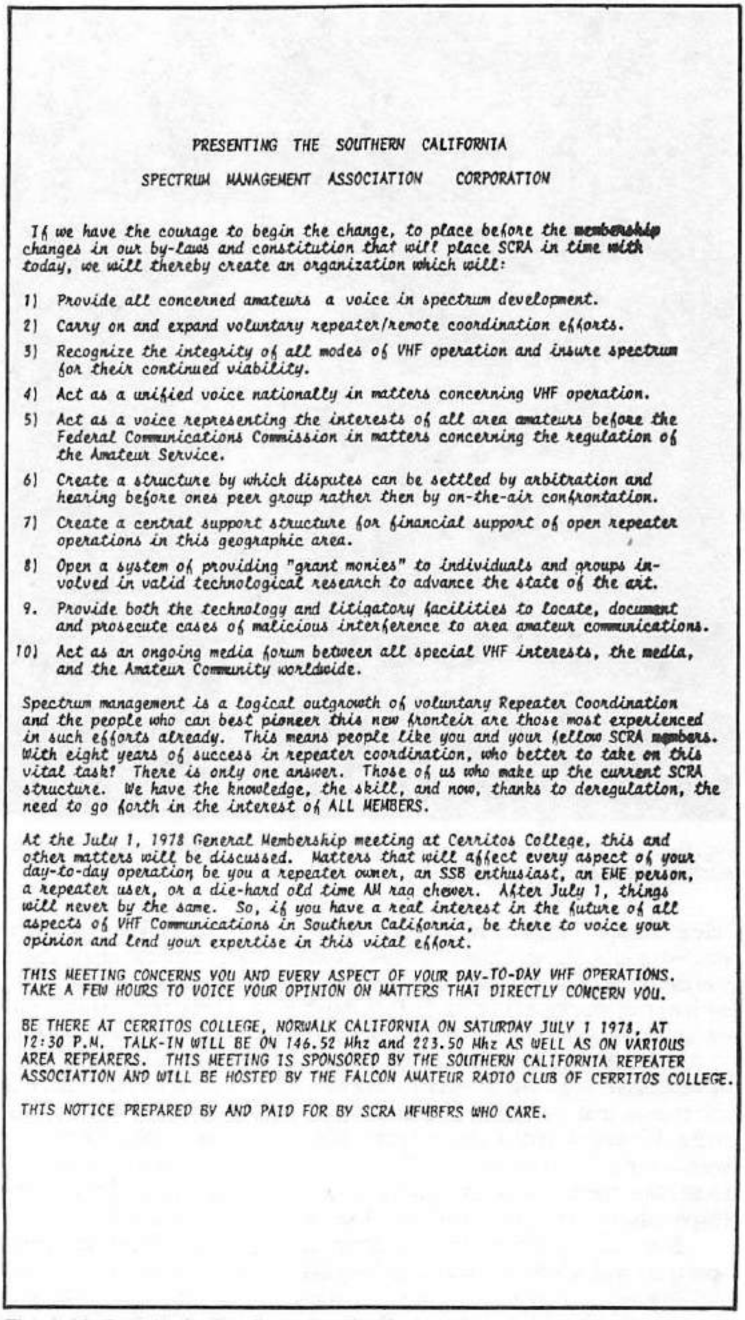


Fig. 9-10. Potential repeater owners in Southern California must complete this map, outlining their intended coverage.



PRESENTING THE SOUTHERN CALIFORNIA

SPECTRUM MANAGEMENT ASSOCIATION CORPORATION

If we have the courage to begin the change, to place before the **membership** changes in our by-laws and constitution that will place SCRA in time **with** today, we will thereby create an organization which will:

1) Provide all concerned amateurs a voice in spectrum development.

2) Carry on and expand voluntary repeater/remote coordination efforts.

3) Recognize the integrity of all modes of VHF operation and insure spectrum for their continued viability.

4) Act as a unified voice nationally in matters concerning VHF operation.

5) Act as a voice representing the interests of all area amateurs before the Federal Communications Commission in matters concerning the regulation of the Amateur Service.

6) Create a structure by which disputes can be settled by arbitration and hearing before ones peer group rather then by on-the-air confrontation.

7) Create a central support structure for financial support of open repeater operations in this geographic area.

8) Open a system of providing "grant monies" to individuals and groups involved in valid technological research to advance the state of the art.

9. Provide both the technology and litigatory facilities to locate, document and prosecute cases of malicious interference to area amateur communications.

10) Act as an ongoing media forum between all special VHF interests, the media, and the Amateur Community worldwide.

Spectrum management is a logical outgrowth of voluntary Repeater Coordination and the people who can best pioneer this new fronteir are those most experienced in such efforts already. This means people like you and your fellow SCRA members. With eight years of success in repeater coordination, who better to take on this vital task? There is only one answer. Those of us who make up the current SCRA structure. We have the knowledge, the skill, and now, thanks to deregulation, the need to go forth in the interest of ALL MEMBERS.

At the July 1, 1978 General Membership meeting at Cerritos College, this and other matters will be discussed. Matters that will affect every aspect of your day-to-day operation be you a repeater owner, an SSB enthusiast, an EME person, a repeater user, or a die-hard old time AM rag chewer. After July 1, things will never by the same. So, if you have a real interest in the future of all aspects of VHF Communications in Southern California, be there to voice your opinion and lend your expertise in this vital effort.

THIS MEETING CONCERNS YOU AND EVERY ASPECT OF YOUR DAY-TO-DAY VHF OPERATIONS. TAKE A FEW HOURS TO VOICE YOUR OPINION ON MATTERS THAT DIRECTLY CONCERN YOU.

BE THERE AT CERRITOS COLLEGE, NORWALK CALIFORNIA ON SATURDAY JULY 1 1978, AT 12:30 P.M. TALK-IN WILL BE ON 146.52 Mhz and 223.50 Mhz AS WELL AS ON VARIOUS AREA REPEARERS. THIS MEETING IS SPONSORED BY THE SOUTHERN CALIFORNIA REPEATER ASSOCIATION AND WILL BE HOSTED BY THE FALCON AMATEUR RADIO CLUB OF CERRITOS COLLEGE.

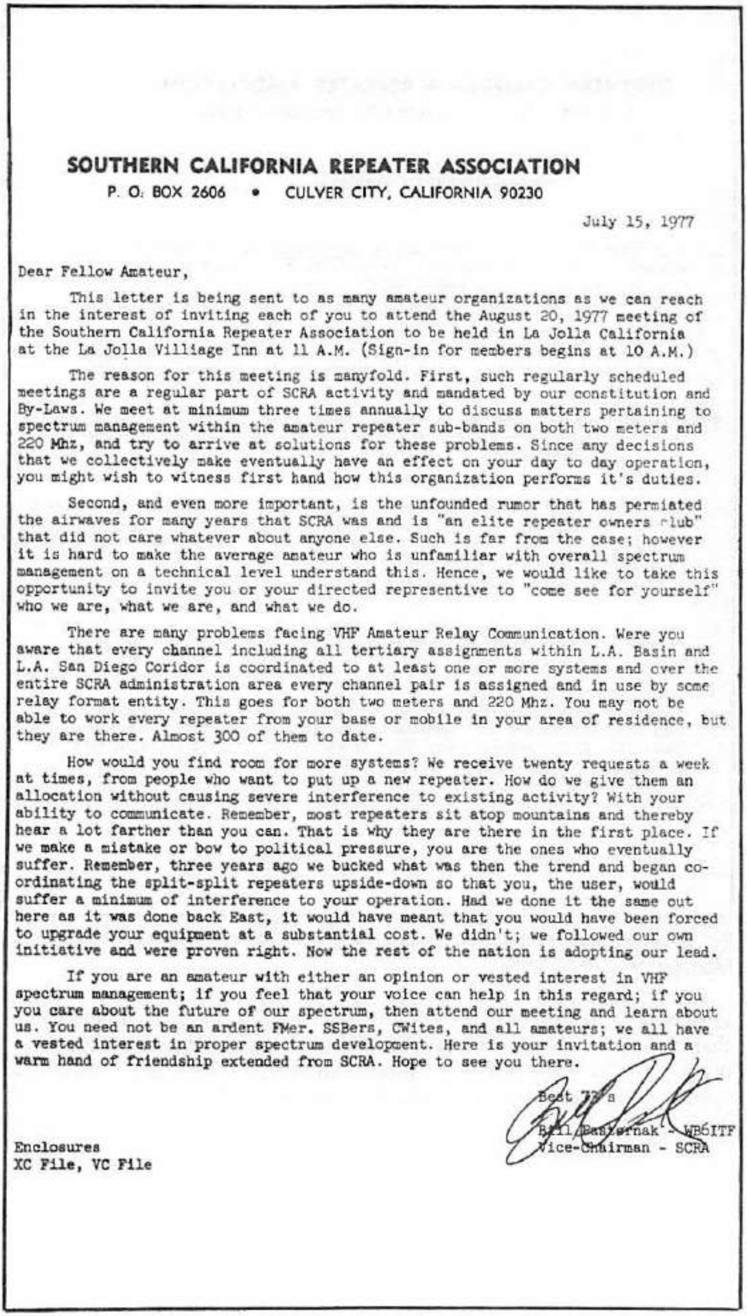
THIS NOTICE PREPARED BY AND PAID FOR BY SCRA MEMBERS WHO CARE.

Fig. 9-11. An introduction to reorganization.

Fig. 9-12. Today, people like Bob Thornburg, WB6JPI, head repeater councils such as TASMA, formerly SCRA.

"clear channel," thus far it has not been the case either in Illinois where it started or in Southern California where it was recently implemented. There you have a good overall picture of what voluntary coordination is all about, such as that displayed in Figs. 9-11 through 9-14. There remains only one question: Why should you, as a potential repeater owner/operator, bother to coordinate your repeater, remote-base, simplex autopatch, translator, or what have you? The answer to that should be obvious by now, and it is the reason that over 3300 repeaters have already gone the coordination route. We are all part of a community. We join that community the day our license arrives in the mailbox. With it comes a certain moral responsibility to all other members of that community and, while not legally binding, the responsibility exists nevertheless. Also, why ask for trouble?

Here in the United States, Amateurs are lucky. They are given spectrum with which they can do as they like within the bounds in the Rules and Regulations that guide the amateur Radio Service. It's a priviledge that is very special, and one that most amateurs cherish. Worldwide not all



SOUTHERN CALIFORNIA REPEATER ASSOCIATION
P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

July 15, 1977

Dear Fellow Amateur,

This letter is being sent to as many amateur organizations as we can reach in the interest of inviting each of you to attend the August 20, 1977 meeting of the Southern California Repeater Association to be held in La Jolla California at the La Jolla Villiage Inn at 11 A.M. (Sign-in for members begins at 10 A.M.)

The reason for this meeting is manyfold. First, such regularly scheduled meetings are a regular part of SCRA activity and mandated by our constitution and By-Laws. We meet at minimum three times annually to discuss matters pertaining to spectrum management within the amateur repeater sub-bands on both two meters and 220 Mhz, and try to arrive at solutions for these problems. Since any decisions that we collectively make eventually have an effect on your day to day operation, you might wish to witness first hand how this organization performs it's duties.

Second, and even more important, is the unfounded rumor that has permiated the airwaves for many years that SCRA was and is "an elite repeater owners club" that did not care whatever about anyone else. Such is far from the case; however it is hard to make the average amateur who is unfamiliar with overall spectrum management on a technical level understand this. Hence, we would like to take this opportunity to invite you or your directed representive to "come see for yourself" who we are, what we are, and what we do.

There are many problems facing VHF Amateur Relay Communication. Were you aware that every channel including all tertiary assignments within L.A. Basin and L.A. San Diego Coridor is coordinated to at least one or more systems and over the entire SCRA administration area every channel pair is assigned and in use by some relay format entity. This goes for both two meters and 220 Mhz. You may not be able to work every repeater from your base or mobile in your area of residence, but they are there. Almost 300 of them to date.

How would you find room for more systems? We receive twenty requests a week at times, from people who want to put up a new repeater. How do we give them an allocation without causing severe interference to existing activity? With your ability to communicate. Remember, most repeaters sit atop mountains and thereby hear a lot farther than you can. That is why they are there in the first place. If we make a mistake or bow to political pressure, you are the ones who eventually suffer. Remember, three years ago we bucked what was then the trend and began co-ordinating the split-split repeaters upside-down so that you, the user, would suffer a minimum of interference to your operation. Had we done it the same out here as it was done back East, it would have meant that you would have been forced to upgrade your equipment at a substantial cost. We didn't; we followed our own initiative and were proven right. Now the rest of the nation is adopting our lead.

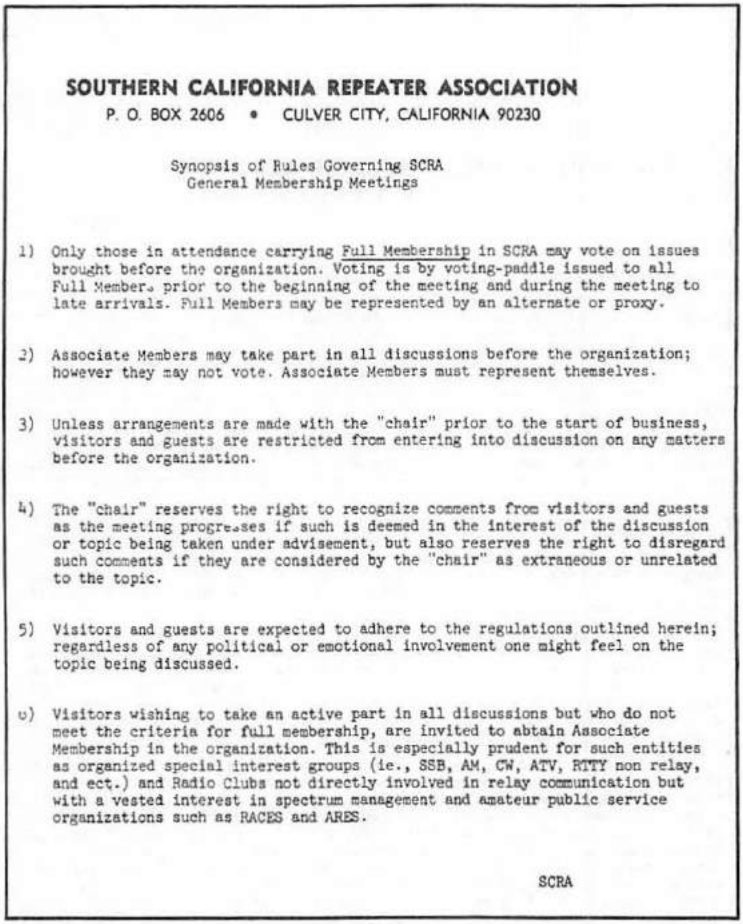
If you are an amateur with either an opinion or vested interest in VHF spectrum management; if you feel that your voice can help in this regard; if you you care about the future of our spectrum, then attend our meeting and learn about us. You need not be an ardent FMer. SSBers, CWites, and all amateurs; we all have a vested interest in proper spectrum development. Here is your invitation and a warm hand of friendship extended from SCRA. Hope to see you there.

Best 73's

Bill Pasternak - WB6ITF
Vice-Chairman - SCRA

Enclosures
XC File, VC File

Fig. 9-13. A letter sent to many clubs to initiate spectrum management.



SOUTHERN CALIFORNIA REPEATER ASSOCIATION

P. O. BOX 2606 • CULVER CITY, CALIFORNIA 90230

Synopsis of Rules Governing SCRA
General Membership Meetings

1) Only those in attendance carrying Full Membership in SCRA may vote on issues brought before the organization. Voting is by voting-paddle issued to all Full Members prior to the beginning of the meeting and during the meeting to late arrivals. Full Members may be represented by an alternate or proxy.

2) Associate Members may take part in all discussions before the organization; however they may not vote. Associate Members must represent themselves.

3) Unless arrangements are made with the "chair" prior to the start of business, visitors and guests are restricted from entering into discussion on any matters before the organization.

4) The "chair" reserves the right to recognize comments from visitors and guests as the meeting progresses if such is deemed in the interest of the discussion or topic being taken under advisement, but also reserves the right to disregard such comments if they are considered by the "chair" as extraneous or unrelated to the topic.

5) Visitors and guests are expected to adhere to the regulations outlined herein; regardless of any political or emotional involvement one might feel on the topic being discussed.

6) Visitors wishing to take an active part in all discussions but who do not meet the criteria for full membership, are invited to abtain Associate Membership in the organization. This is especially prudent for such entities as organized special interest groups (ie., SSB, AM, CW, ATV, RTTY non relay, and ect.) and Radio Clubs not directly involved in relay communication but with a vested interest in spectrum management and amateur public service organizations such as RACES and ARES.

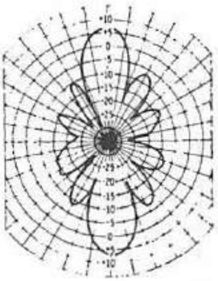
SCRA

Fig. 9-14. Typical repeater council meeting rules prior to change to Spectrum Management Association.

amateurs have such privileges. In most cases, it's the government rather than one's peer group which decides if you can or cannot place a repeater in operation and what pair of channels. In America, we have something special—and voluntary coordination is one way of keeping it.

Chapter 10

Bandplans and Bandplanning



The orderly growth of amateur repeater communication has meant that amateurs had to undertake something they had never attempted before. To avoid haphazard growth patterns, lines of dialogue and cooperation were needed between these relay-minded hams, and from this need grew the concept of voluntary repeater coordination. However, this dialogue in whatever form it takes, is but the vehicle. What makes this endeavor meaningful is having some sort of plan to keep repeaters from stepping on one another's toes. Over the years, various amateur organizations, along with ARRL's VHF Repeater Advisory Committee, have developed and implemented such plans on a national, regional, or local basis.

BANDPLAN TYPES

There are two types of bandplans (see Tables 10-1 through 10-14). Repeater Sub-Band bandplanning, wherein repeater owner/operators have segregated themselves from all other activities into FCC designated sub-bands, and overall spectral planning wherein all amateurs help in developing operational guidelines for an entire amateur band. In the case of the latter, only 2-meters has such a plan in the early stages of national implementation. Looking at the former, we note that many plans abound for the sub-bands. In fact, there is total national agreement in relation to only one repeater sub-band as this is written in early 1979—the amateur 220 MHz band. In the case of all other bands, there is still some inter-regional disagreement as to which plan works best.

As you will see from the charts on the following pages, bandplans abound, and what is in use in one area on a given band may not be the same elsewhere. That is not meant to imply that no standardization exists whatsoever, since, in the case of the most developed band, 2 meters, certain national standards have been accepted. However, even here an ongoing East-West controversy still exists over the split-split channels, with the East operating non-inverted to protect the relay systems, and the West inverting these channel pairs in deference to the system users. There is also another East-West disagreement concerning 450-MHz operation, with one side favoring high in/low out and the other side favoring the opposite. No nationally accepted plans exist for 10 meters, 6 meters, or the spectrum above 450 MHz. However one group, the Southern California Repeater Remote Base Association has fielded and implemented plans for all the above, up to and including the microwave region. The only spectrum

Table 10-1. A 10-meter QRP bandplan.

Originator: 73 Magazine, Peterborough, NH 03458

CHANNEL	FREQUENCY (MHz)	UTILIZATION
1	28.965	Listening and Calling
2	28.975	Autocall Monitoring
3	28.985	County Hunting—non ragchew
4	29.005	Beacon Monitoring
5	29.015	
6	29.025	Rag Chewing (lowest)
7	29.035	
8	29.055	
9	29.065	
10	29.075	
11	29.085	
12	29.105	
13	29.115	
14	27.125	
15	29.135	
16	29.155	
17	29.165	
18	29.175	
19	29.185	Repeater Channel
20	29.205	RTTY
21	29.215	Oscar Coordination
22	29.225	
23	29.255	SSTV
24	29.235	
25	29.245	Repeater
26	29.265	Repeater
27	29.275	Repeater
28	29.285	
29	29.295	
30	29.305	
31	29.315	
32	29.325	
33	29.335	
34	29.345	
35	29.355	
36	29.365	
37	29.375	
38	29.385	
39	29.395	
40	29.405	Oscar Listening

Recommended Mode(s) QRP AM/SSB except as noted
Repeater Channels used in conjunction with input or output on another band.

SCRRBA has not dealt with is 2 meters and 220 MHz, as these are the domain of other coordinating organizations.

It should be stated that the very first workable 2-meter bandplan was one from Texas in the late 1960's called, appropriately enough, the Two-Meter Texas Plan. Until the time of the Texas Plan, all attempts at organized coordination were based upon 60-kHz separation between sys-

Table 10-2. A 10-meter QRP bandplan from California.

Originator: Southern California AM/SSB QRP Band Planning Council
West Hollywood California

CHANNEL	FREQUENCY AM (MHz)	FREQUENCY SSB (MHz)
1	28.760	28.560
2	28.770	28.570
3	28.780	28.580
4	28.800	28.600
5	28.810	28.610
6	28.820	28.620
7	28.830	28.630
8	28.850	28.650
9	28.860	28.660
10	28.870	28.670
11	28.880	28.680
12	28.900	28.700
13	28.910	28.710
14	28.920	28.720
15	28.930	28.740
16	28.950	28.750
17	28.960	28.760
18	28.970	28.770
19	28.980	28.780
20	29.000	28.800
21	29.010	28.810
22	29.020	28.820
	29.030	28.830
23	29.050	28.850

Note 1: Bandplan is subdivided into two parallel operations for SSB and AM
Overlap exists between modes to provide intercommunication.

Note 2: No specific activities assigned to given channel. Activities are local option.

tems, this due to the wide-band nature of many early Amateur relay experiments. With the advent of the Texas Plan, the day of wide-band was ended, and channel separation became 30 kHz. In some areas, the 30 kHz, or 30-kHz split, channels were quickly filled. The term 30-kHz split comes from the halving of the original 60-kHz channels to effectively double the number of available channel pairs. In the early seventies, some locations

Table 10-3. A 10-meter FM bandplan.

ORGINATOR: Southern California Repeater/Remote Base Association
Pasadena, California

29.500—Simplex
29.600—Simplex
Channel spacing—20Khz—16F3 emission
Repeater pair spacing—100 kHz
29.50—29.55 MHz—OSCAR Protection

Repeater Pairs
1 29.52—29.62
2 29.54—29.64
3 29.56—29.66
4 29.58—29.68

All repeaters will be tone access (CTCS preferable) for shared channel use and protection against A1, A3, and A3J sporadic signals.

ORIGINATOR: ARRL/VRAC, Newington Conn. 06111
29.3—29.4 Radiosport Satellite
29.4—29.5 Oscar 7 and 8 Downlink
29.52—29.58 Repeater inputs
29.60 Simplex
29.62—29.68 Repeater Outputs

Repeater Pairs (input/output)
29.52—29.62
29.54—29.64
29.56—29.66
29.58—29.68

Table 10-4. 10-meter FM bandplan from ARRL/VRAC.

again split the separation thereby creating 15-kHz—or split-split—channels. Here is where one controversy arose. The Northeast was the first to implement split-split operation, and did so right-side-up. That is to say that, if a repeater input was 146.01 MHz, the next repeater input became 146.025 MHz. In a like manner, the outputs were adjoining, placing 146.625 next to 146.61. This plan, known under several names including the Modified Texas Plan or Northeast Repeater Association Two-Meter Plan, is designed to protect repeaters from interfering with one another, and does so effectively. However, as with everything, there is a cost and in this case it is the system user who pays. For such a system to work on a large scale requires that every user have a radio capable of separating adjacent high-power repeater signals 15 kHz apart. Unfortunately, much of the early Amateur equipment in use at the time did not have such selectivity, and none was on the market that did. This required the user to modify his existing equipment for tighter selectivity, if it could be done, or to procure newer equipment. In some cases, modification was extensive or impossible because certain radios had no method of adjusting receive crystals to frequency, and many radios—which had functioned flawlessly under 30-kHz separation—were made obsolete by the implementation of the 15-kHz tertiaries. Eventually, manufacturers brought out newer equipment designed to operate in this environment. However, this was a case where growth in certain areas had outstripped equipment availability.

Recognizing the problems inherent to 15-kHz channels, the Southwest initiated a totally different approach. Under its plan, known as the SCRA Two-Meter Bandplan or Southern California Inverted Tertiary Bandplan, the 15-kHz channels were placed upside-down from the 30-kHz channels. It was a move specifically designed to protect the needs of the user by placing the responsibility of handling adjacent-channel interference on the repeater owner/operator. Under this system, the user's receiver always sees a clear 30-kHz channel, unless he happens to be near the user of an adjacent-channel repeater. It was realized that the chance of there being two base operations in the same area was slight, and, if at least one was mobile he/she could simply drive away from the interference source. Though Southern California has better than 28,000 active radios, very few adjacent-channel problems have developed over the nine years this plan has been in use.

Another important factor in this plan takes into consideration the superior technical equipment used in most repeaters, and the higher level of technical ability of most repeater owner/operators. In his analogy in the appendix of this book, Mr. Robert Thornburg, WB6JPI, points out that, in cases where interference does exist, there is less of a problem inherent to a small number of repeater owners working to eliminate it than there is in dealing with thousands of individual users. This plan now predominates in

Table 10-5. Bandplan for 6-meter FM.

Originator: ARRL/VARAC, Newington Conn. 06111 50-MHz Band Plan 1000 kHz spacing: 20 kHz channels		
Simplex	**Repeater Input/output**	**Reverse[1]**
	52.01/53.01	
	52.03/53.03	
	52.05/53.05	
	52.07/53.07	
		52.09/53.09
		52.11/53.11
	52.13/53.13	
	52.15/53.15	
	52.17/53.17	
		52.19/53.19
		52.21/53.21
	52.23/53.23	
	52.25/53.25	
	52.27/53.27	
		52.29/53.29
		52.31/53.31
	52.33/53.33	
	52.35/53.35	
	52.37/53.37	
		52.39/53.39
		52.41/53.41
	52.43/53.43	
	52.45/53.45	
	52.47/53.47	
52.49		52.49
52.51		53.51
52.525 NSF*		
	52.55/53.55	
	52.57/53.57	
		52.59/53.59
		52.61/53.61
	52.63/53.63	
	52.65/53.65	
	52.67/53.67	
		52.69/53.69
		52.71/53.71

[1] The reserve frequencies listed are guard channels for the model radio control frequencies, every 100 kHz from 53.1 through 53.8 MHz. In the event that additional repeater channels are needed, these reserve channels could be allocated. For the present, it is suggested that frequency coordinators do not assign these channels.

*National Simplex Frequency

Table 10-6. 6-meter FM bandplan from California.

Originator: Southern California Repeater Remote Base Association
Pasadena California

Spacing between systems: 20 kHz
Input to Output Spacing: 220 kHz
Emission: 16F3

52 MHz

1.	52.72 MHz	52.50 MHz
2.	52.76	52.525
3.	not available	52.54
4.	52.78	52.56
5.	52.80	52.58
6.	52.82	52.60
7.	52.84	52.62
8.	52.86	52.64
9.	52.88	52.66
10.	52.90	52.68
11.	52.92	52.70

NOTES: Pair #1 not currently available as per FCC #97.64(c). Pair #2 reserved for prime regional "open" repeaters: 52.525 MHz co-shared with simplex (National Simplex Frequency). 52.54 is alternate simplex channel. Pair #6 is reserved for RTTY. I6F3 emissions required. RACES and model vehicle radio control channels above 53.0 MHz are protected. Realignment of repeater inputs plus development of additional simplex channels is due after FCC #97.65(c) is removed.

much of the Southwestern United States and South Central United States, while the non-inverted or Modified Texas Plan is used most other places. Mr. Thornburg's paper gives far greater insight into this question, and is suggested reading for those interested in the subject.

A NEW SUB-BAND

In 1978, the FCC created a second repeater sub-band on 2 meters, and within a month, no less than nineteen repeater plans had come to light from various areas. Only two are included here, since they are the only

Table 10-7. ARRL/VUAC over bandplan for 144-148 MHz.

The following bandplan, developed by the ARRL's VHF/UHF Advisory Committee is designed to meet the needs of all spectrum users. While at this writing it has still not been approved by the ARRL's Board of Directors for national implementation, certain areas of the Southcentral and Southwestern United States have already adopted its use.

144.0—144.05—EME (cw)
144.05—144.06—Propagation Beacons
144.06—144.10—General CW (including weak signal)
144.10—144.20—Weak-signal SSB (including EME)
144.20—144.30—General SSB (rag-chewing, nets, etc)
144.30—144.50—Satellites (AMSAT Phase 3 High Altitude)
144.50—144.90—Repeater Inputs (144.5—144.6 reserved for linear translators/ SSB repeaters)
144.90—145.10—Weak Signal and FM Simplex
145.10—145.50—Reapter Outputs (145.1—145.2 reserved for linear translators/ SSB repeaters)
145.50—145.80—Miscellaneous and experimental modes. (Also suggested AM)
145.80—146.00—Satellites
146.00—148.00—FM repeaters.

Table 10-8. 2-meter FM bandplan for the lower segment.

Originator: Northern Amateur Relay Council (Originator) Stockton California and ARRL/VRAC, Newington, Conn. 06111

All inputs low, outputs high (a quick check shows that the least harmful intermods occur to weak signal and Oscar work above the new band segment.)

A total of 20 channels, 20 kHz spacing, no splits. The first channel starts at 144.51, the last at 144.89 Input/output spacing. 600 kHz. The section from 144.9 to 145.1 (200 kHz) is reserved for non-channelized communications, weak signal, SSB, etc So, the band would be as follows:

Input/Output	
144.51/145.11	144.71/145.31
144.53/145.13	144.73/145.33
144.55/145.15	144.75/145.35
144.57/145.17	144.77/145.37
144.59/145.19	144.79/145.39
144.61/145.21	144.81/145.41
144.63/145.23	144.83/145.43
144.65/145.25	144.85/145.45
144.67/145.27	144.87/145.47
144.69/145.29	144.89/145.49

144.9 to 145.1, 200 kHz reserved for weak signal, SSB, etc

ones implemented. The first is the NARC, or Northern Amateur Relay Council of California, plan which is an FM-only plan for repeater and simplex operation. This plan has been endorsed by the ARRL and its VRAC for recommended national implementation. The second one presented is the TASMA/SCRA plan, under wide-spread use in Southern California, and was based on recognition of all existing 144.5 to 145.5 MHz activity and activity up to, and including, AMSAT/OSCAR operations. The TASMA/SCRA Plan covers all activity from 144.5 to 146.00 MHz, where it joins the existing 146.0 to 148.0-MHz repeater bandplan. Both of these are based on

Table 10-9. 144.5—145.5 MHz bandplan from SCRA/TASMA

Repeaters in the spectrum between 144.5 to 145.5 MHz utilize a "low in/high out" configuration, on nineteen even numbered numbered channels. Channel pairs are numbered 01 to 19 and begin with 144.52 being channel 01 and 14488 being channel 19. Spacing is 20 kHz between repeater systems and 600 kHz between repeater inputs and outputs. Channel pairs o1 and 02 are for use only by non-FM relay devices such as in-band Linear Translators and/or SSB Repeaters. Channel pairs 12 and 18 are held as "Clear Channel for Baja Mexico Operations" by aggreement with the Baja Coordination Council and NO SOUTHERN CALIFORNIA—U.S. OPERATIONS WILL BE COORDINATED TO THEM. We urge all U.S. Amateurs to abide by this agreement. Channel pairs 03 and 19 are multicoordinated to "Private" category repeaters only. No "Open" or "Closed" category operations. All other channels are for "Open" and "Closed" category operations. All FM systems operating in this spectrum are required the use of CTCS tone access, with "open" category tone access assigned by the technical committee at time of coordination. "Private" and "Closed" category systems may choose their own CTCS access tone; however it must be approved by the technical committee at time of coordination to prevent duplication and thereby create co-channel problems. All repeater pairs are Co-Channeled to two or more systems.

Simplex is non-channelized from 144.9 to 145.1 MHz and non-FM operation is recommended.

Table 10-10. National 2-meter FM bandplan, 146-148 MHz.

This bandplan is a compilation of input derived from various sources and represents virtually all US. Canadian, and Mexican Amateur repeater activities found in ITU Region 2. We wish to acknowledge the following sources of input:

American Radio Relay League
VHF Repeater Advisory Committee ARRL
Texas VHF FM Association
Mid-Atlantic Repeater Council
S.C.R.A. T.A.S.M.A.
Repeater Council of Baja, Calif.
Northern Amateur Relay Council
Tri-State Amateur Repeater Assn

Description

General:

Separation Between Systems: 30 kHz nominal, 15 kHz where utilized
Input to Output Separation: 600 kHz
Modulation: 16F3; plus minus 5 kHz deviation

Spectrum Utilization:

146—148 Mhz: All 30 kHz Channels operate input low—output high; 15 kHz Channels are non-inverted under Texas Plan and Inverted under SCRA Plan.
147—148 MHz: All 30 kHz Channels operate input high—output low; 15 kHz Channels are non-inverted under Texas Plan and inverted under SCRA Plan.
Check with local coordinator or coordination council as to which plan is utilized for 15 kHz systems in your area.

Simplex (FM)

146.43—ATV Calling and Voice Carrier Channel
146.46—National Remote Base Intertie Intercom Channel
146.49—Regional
146.52—National
146.55—National
146.58—National
147.45—Regional
147.48—Regional
147.51—National
147.54—National
147.57—National: Amateur related volunteer law enforcement or search and rescue operations in some areas.

Repeater Channels: (Shown with inverted 15 kHz Tertiaries—SCRS TASMA Plan)
146—148 MHz (MHz designation deleted)

input	output	input	output
.01	61	.865	.265
.625	.025	.28	.88
04	64	.895	.295
.655	055	.31	.91
07	67	925	.325
.685	085	.34	.94
10	70 (RTTY)	955	.355
715	015	.37	.97
13	73	985	.385
745	145	.40	7.00*
16	76		
775	175		
19	79		
.805	205		
.22	82		
.835	235		
.25	85		

*Some areas utilize 147.00 in combination with 147.60 as a repeater pair. Check with local coordinator/coordination council.

147—148 MHz (MHz designation deleted)

input	output	input	output
60	7.00*	255	855
015	615	87	.27
63	03	285	855
075	675	90	.30
69	09	315	915
105	705	93	33
72	12	345	945
135	735	96	36
75	15	375	975
165	765	99	39
78	18		
195	795		
81	21		
225	825		
84	24		

*Some areas use 147.00 in combination with 146.40 as a repeater pair

EXCEPTIONS

A) In the Northeast, one will find a number of 1 MHz input-to-output separation systems. These repeaters are generally located in the Metro New York/New Jersey area. Consult local repeater directory.

B) In the Los Anglees, California, area, one very popular open repeater operates on 1.035-MHz input-to-output separation input. 147.435/output 146.40 MHz

NOTES

1) Tertiary (15-kHz) channels are listed using California Inverted Tertiary Plan which has become widely adopted. However, your area may use a non-inverted plan. Check with your local coordinator or coordination council

2) More than one repeater may be coordinated to a given channel in your area. Check with coordinator/coordination council

3) Listings of worldwide repeater operation are available from various sources. Consult amateur periodicals

4) Area repeater listings are usually published by local coordinators or coordination councils.

5) Some areas are instituting tone-access for all operations. Consult local coordinator or coordination council

6) This is a general activities outline subject to local option

Table 10-11. National 220-MHz Bandpan

Sources: ARRL, VRAC, 73 Magazine, Tri-State Amateur Repeater Assn., 220-Spectrum Management Association of Southern California, various other Amateur repeater councils and coordinators.

Emission: 16F3; plus/minus 5-kHz deviation
Spacing between repeaters: 40 kHz; 20 kHz regional option indicated by *
Input to output spacing: 1.6 MHz; low in/high out

Simplex:

223.42
223.44*
223.46
223.48*
223.50 National
223.52*
223.54
223.56*
223.58
223.60*
223.62
223.64*
223.66
223.68*
223.70 RTTY
223.72*
223.74
223.76*
223.78
223.80*
223.82
223.84*
223.86
223.88*
223.90

Repeater Channel Pairs

input	output	input	output
222.02	223.62	222.78	224.38
222.04	223.64*	222.80	224.40*
222.06	223.66	222.82	224.42
222.08	223.68*	222.84	224.44*
222.10	223.70	222.86	224.46
222.12	223.72*	222.88	224.48*
222.14	223.74	222.90	224.50
222.16	223.76*	222.92	224.52*
222.18	223.78	222.94	224.54
222.20	223.80*	222.96	224.56*
222.22	223.82	222.98	224.58
222.24	223.84*	223.00	224.60*
222.26	223.86	223.02	224.62
222.28	223.88*	223.04	224.68*
222.30	223.90	223.06	224.66
222.32	223.92*	223.08	224.60*
222.34	223.94	223.10	224.70
222.36	223.96*	223.12	224.72*
222.38	223.98	223.14	224.74
222.40	224.00*	223.16	224.76*
222.42	224.02	223.18	224.78
222.44	224.04*	223.20	224.80*
222.46	224.06	223.22	224.82
222.48	224.08*	223.24	224.84*
222.50	224.10	223.26	224.86
222.52	224.12*	223.28	224.88*
222.54	224.14	223.30	224.90
222.56	224.16*	223.32	224.92*
222.58	224.18	223.34	224.94
222.60	224.20*	223.36	224.96*
222.62	224.22	223.38	224.98
222.64	224.24*		
222.66	224.26		
222.68	224.28*		
222.70	224.30		
222.72	224.32*		
222.74	224.34		
222.76	224.36*		

Table 10-12. ARRL 450-MHz FM bandplan.

SOURCE: ARRL/VRAC, Newington, Conn. 06111	
450-MHz Band Plan	
442.00—444.95	Repeater Outputs
445.00—446.95	Simplex, Aux links
446.00	National Simplex Frequency
447.00—449.95	Repeater Inputs

Notes: Repeater input/output spacing is 5 MHz, 50 kHz channel spacing. It is suggested that frequency coordinators do not assign 442.00 MHz as an output but start at 442.050 MHz. Because 442.00 is a subband edge, a repeater output on exactly 442.00 MHz could be in violation of the FCC rules if a portion of the signal extended below the center frequency.

20-kHz spacing between systems and 600-kHz input-to-output separation. Other plans for this sub-band revolve around such items as 30-kHz separation between repeaters, and using 15 kHz tertiaries, either inverted or non-inverted. There is one plan that calls for 300-kHz input-to-output separation, while others recommend high in/low out, rather than the low in/high out which has been accepted for this sub-band's use.

Of all the plans in this chapter, only one can be said to have total national acceptance and implementation; this is the 220-MHz bandplan which was developed simultaneously by many groups and accepted by the ARRL and VRAC. This plan uses initial 40-kHz separation between repeaters, and 1.6-MHz input-to-output separation. To my knowledge, no other coordination plan is in use for this particular band.

Table 10-13. SCRRBA 450-MHz FM bandplan.

SOURCE: Southern California Repeater Remote Base Assn., Pasadena, Calif.	
420 — 450 MHz	
GENERAL: 420-430 MHz	**Duplex link pairs**
430-432	**One way links**
438-440	**One way links**
440-450	**Mobile relay inputs and outputs**
440-450 MHz:	25 kHz channel spacing; 5.000 MHz input/output separation; inputs from 440.0 to 444.975 MHz; outputs 445.0 to 449.975 MHz, 16F3 emissions required;0.0005% frequency stability of transmitters recommended; CTCSS strongly encouraged. Non-coordinated, general use "ground test" pair; 441.875 MHz (input), 446.875 MHz (output). Simple is at 446.000 and 446.500 MHz.
420-430 MHz:	25 kHz channel spacing, 0.0005% frequency stability of transmitters recommended. 16F3 emissions preferred; wider bandwidths may be coordinated if necessary for special system requirements. Exact frequencies and input/output spacings are individually coordinated. Simplex: 426.000 MHz.

Table 10-14. 1215-1300 MHz bandplan.

Originator: Southern California Repeater Remote Base Assn., Pasadena, California			
SCRRBA 1215-1300 MHz Band Plan			
Segment	**Use**	**Pairs with**	**Notes**
1215-1220 MHz	Data commun.	1230-1235 MHz	
1220-1224	Mod. oscil.		APX-6
1224-1230	ATV Repeater/ translator output (auxil)	1264-1270	Video carrier at 1225.25 MHz
1230-1235	Data commun.	1215-1220	
1235-1238	FM repeater outputs (auxil)	1251-1254	
1238-1240	Point-to-point voice links		simplex, aux links, etc.
1240-1249	ATV repeater/ translator output (inband)	1280-1290	Video carrier at 1241.25 MHz
1249-1251	Weak signal guard band		1250 MHz weak signal window
1251-1254	FM repeater input (auxil)	1235-1238	
1254-1264	FM repeater input	1270-1280	36F3 emissions, 40 kHz channels
1264-1270	ATV repeater/ translator output (cross band)	1224-1230 & 434 MHz	Video carrier at 1265.25 MHz
1270-1280	FM repeater output	1254-1264	36F3 emisions; 40 kHz channels
1280-1290	ATV repeater/ translator input (inband) and simplex	1240-1249	Video carrier at 1282 MHz
1290-1295	Satellite		
1295-1297	Weak signal guard band		1296 MHz weak signal window
1297-1300	Satellite		

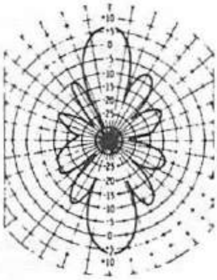
10 METERS

As to 28 MHz, we will be presenting a number of plans, including those of SCRRBA and the VRAC. Also for ten, we list two AM/SSB simplex QRP bandplans. While not exactly within the realm of FM relay communication, they nonetheless represent a growing portion of today's VHF activity. The plans listed come from *73 Magazine* and The Southern California AM/SSB QRP Bandplanning Council. Both represent serious attempts at providing organization for this activity.

One final note. Before attempting to place a repeater into operation, it is advisable to check with local coordination authorities as to exactly what is in use in your area. This also holds true for 10-meter AM/SSB QRP operations, and should be done prior to converting that CB radio to 10 meters.

Chapter 11

Introduction to Repeater Design



The purpose of this section is to give you some pointers on designing a system, and to help you avoid the past errors of many people and groups. If there is one hard and fast rule in system design, it would be: plan ahead. Try to have an alternative plan for any contingency. Don't build into your system before you start.

When you sit down to plan your system, either as one person or a group, think large. Throw away any financial and equipment-availability limitations, and draw your dream system. If it is a group project, let each member do it independently, then combine all the ideas into one huge drawing. It may look unwieldy, but remember, a camel is a horse designed by a committee. When you have this dream system on paper, let it sit a month, then look at it again. If you still like it, then skip the next sentence. If you don't like it, change it and let it stand another month. Once the system design has been finalized, mark in red pencil the absolute minimum parts needed to get started, and start building. The reason for all this? You don't want to build yourself into a hole. One group that I talked to had a nice system, running smoothly, and then one of the members wanted to add WWV and weather receivers. He offered to acquire and build the units, including the antennas, lightning arrestors, and so on at no cost to the club. He was turned down because there were no more ports on the audio switcher, only one spare command function in the control system, and neither was designed for expansion! Somebody didn't plan ahead—or ask each member what should be in the system on a long-range basis.

I recommend the following steps in building your repeater system:

- Build a duplex base. This is the RF hardware set up as it would be in a repeater, but not repeating. It does, however, allow RF debugging, tuning, desense-chasing, noise reduction, etc. Once the duplex base is fully operational, then, and only then, should you go any further.
- The second step is simple, local-control repeaters, sometimes known as "kerchunk-boxes." This is basically a duplex base, with a hang-in timer, a time-out timer, a method of coupling audio from the receiver to the transmitter, some switches to control it, and maybe a CW identifier. Don't forget the rack to house it all.
- The third step can be wireline-control techniques. Wireline techniques look simple on the surface, but can be quite complex in the real world. Even if you want to control your system by radio, you might end up with a split-site that is connected by a wireline.

- Next, you can go to tone-control techniques and formats. These techniques could be combined with wireline, or be used by itself.
- Then you can get into the control of supersystems; the techniques that have been proven in networks of two to ten sites in one repeater, or of many separate repeaters.

A word of caution: Do not try to build any system without first building a duplex base, then a small system. Make both play *well*, and then enlarge it.

> "Practice yourself, for Heaven's sake, in little things, and thence proceed to greater." *Epictetus, Discourses, Chapter 18.*

HARDWARE IMPLEMENTATION

Design your power supply to handle three times the load that you expect to need. One contributor's system ended up using almost twice the design expectation, but since he had planned for three times, he still had some reserve capacity.

Design your power supply so that the load won't be affected if the AC line voltage varies from 95 to 130 volts (assuming a 115V line). If you are using a battery-charger and battery on a 12V system, then design your charger for that AC variation.

Design your power supply with overvoltage protection. If your series-pass transistor shorts, will it put 10 to 20 volts on your 5-volt buss, and blow the tops off every chip in the system? A Zener diode firing a SCR which will blow a fuse is cheap protection. Some groups are using the S-100 hobby-computer-buss technique—an unregulated supply at about +8 or +9V, and a 3-lead regulator on each board. One group is using both the S-100 and the Zener-SCR-fuse ideas.

One thing that some manufacturers of these 3-terminal regulators don't tell you is what will happen if RF gets into their units: they lose all control, and the input voltage appears at the output. Some of the author's friends know all about that—one blew up a Standard 2-meter hand-held unit, and another blew up a Motorola 6-meter PT-200 pack set. They were tuning up the transmitters, using a power supply instead of a battery, and apparently enough RF got back up the clip leads, and into the supply, to cause the regulator to lose control and put full unregulated voltage on the radio and blow the transmitter. Extra bypassing, and maybe an RF choke in the output lead of the supply, is cheap insurance.

EASE OF MAINTENANCE

Use plug-in boards for your repeater control, and your system control. Keep a spare board of each type on hand, and if the boards have adjustments on them, make sure that the adjustments on the spare boards are preset. The ideal situation would be that once the problem had been isolated to one particular board, that board would be replaced to get the system operational. The bad board could then be diagnosed, the defective component replaced, and the now good board would become the spare. Naturally, sockets should be used for any ICs.

Standardize your power pins. The last thing you need is to blow up a card by plugging it into the wrong slot. The Vector 3677 and 3677-2 are excellent, and are available from many hobby/computer stores.

Use lots of LEDs on your cards. Yes, they use a lot of current, but there are ways to reduce that. One way is to run all the LEDs to a common point, and then switch the common point to the voltage need to enable the LEDs. A suitable circuit is shown in Fig. 11-1A. Figure 11-1B shows a way to use 7406 or 7416 (inverting) and 7407 or 7417 (non-inverting) chips as LED drivers. The author uses at least one per board, and after the board is working, the chip is unplugged. Either of these techniques can cut the power consumption up to an ampere (100 LEDs at 10 mA each) in a large system.

Provide plenty of test points. If you use on-board regulator chips, you will want to have a +5V test point, a ground point, and a few points in the logic circuitry at carefully selected places. Mounting these points on the edge of the card allows maintenance to be done without shutting down the system. I've used test-point connectors made by E.F. Johnson, and by Augat. Some part numbers are shown below. These test-point jacks mount conveniently in an IC layout using standard 0.052-inch holes separated 0.4 inch. The jacks are available in 10 colors, and take a standard test probe.

Color	**E.F.J.**	**Augat, Inc.**
red	105750-003	8041-1G4-1
orange	105750-004	8041-1G5-1
yellow	105750-005	8041-1G2-1
green	105750-006	8041-1G7-1
blue	105750-007	8041-1G8-1
violet	105750-008	8041-1G11-1
grey	105750-009	8041-1G10-1
brown	105750-002	8041-1G3-1
black	105750-001	8041-1G6-1
white	105750-010	8041-1G9-1

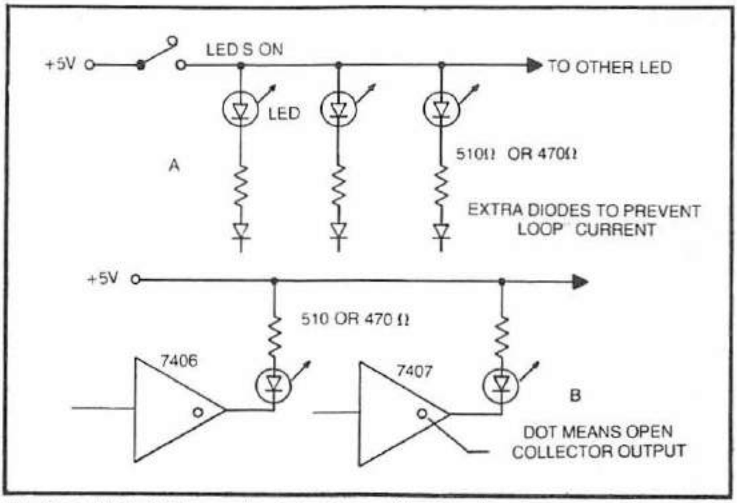

+5V
LED S ON
TO OTHER LED
LED
A
510Ω OR 470Ω
EXTRA DIODES TO PREVENT LOOP CURRENT
+5V
510 OR 470 Ω
7406
7407
B
DOT MEANS OPEN COLLECTOR OUTPUT

Fig. 11-1. Using LEDs and resistors to monitor circuit performance, A, and 7406 ICs as LED drivers, B.

DOCUMENTATION

Keep good documentation. This cannot be overstressed. The authors have seen too many systems that could not be worked on by anyone other than the designer/builder. Many times the designer/builder himself can't remember how something works, or what a wire is for, two years later, and ends up tracing the circuit. Unfortunately, "that" wiring is usually all the same color, since it came from the same roll.

If you are going to spend big money on a system, spend $10 on an assortment of 100-foot rolls of colored wire, and color-code all your system wiring!

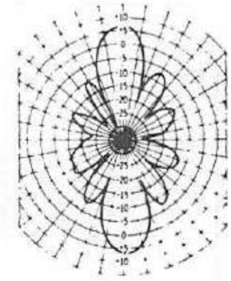
As to the depth of the documentation, decide by asking this question: If you were to die tommorrow, could N______ maintain (or even rebuild) the system with nothing but the documentation? (fill in the N______ with the name of someone from your club who is technically competent, but knows nothing about the system.)

NOISY ENVIRONMENT

Don't leave any input of any gate or flip-flop unconnected. These leads make nice antennas, and they feed nice rectifiers. Suddenly, RF-noise pulses raise havoc with your control logic—although it worked fine in your shop. Texas Instruments has a fine dissertation about unused gate inputs in their TTL Data Manual. Their recommendations about flip-flop inputs can be found on page 60 and 61 of the First Edition of their Data Manual.

A good example of the proper technique of using 1K-ohm pullup resistors is in the identifier section of the repeater controller that was used at the 1978 ARRL convention in San Diego. The recommendation is one resistor for every 25 inputs. That, plus some wire and a little time, will save the builder, fixer, owner, control-operators, and maybe the users, a lot of grief.

Chapter 12
A Repeater You Can Build



In this section, we'll teach you how to build a basic 220-MHz repeater, using the parts from a Clegg FM-27 transceiver. We'll add the necessary interface circuitry and accessories to provide a complete 220-MHz repeater.

Building a repeater is not difficult if you totally understand how the component parts work, and what part they play in the completed unit. Thanks to Ed Clegg and Bob Rauch of Clegg Communications, we are permitted to reprint portions of the manual for an FM-27 transceiver, and to use these as a guide in constructing first a duplex base, then a repeater. Whether you use an FM-27, or any other transceiver, as the foundation for your machine, study its workings thoroughly. Before you break it into separate parts, know and understand the function of each section, and check it out for reliable operation as a transceiver.

THE BASIC REPEATER

The following pages describe how to convert a Clegg FM-76, 220-MHz radio into a functioning duplex base, and how to add the necessary audio and control circuitry. This is not intended to be a step-by-step set of instructions, in the manner of Heathkit, but rather as a set of guidelines that will lead to a working repeating system.

The old Bugs Bunny/Elmer Fudd cartoon recipe for rabbit stew always started out with the first instruction, "First go out and catch the wabbit." At this point we assume you have already caught your Clegg. If not, you can purchase one from Clegg Communications, Lancaster, PA 17602.

Once you have your radio, be it a Clegg or any other brand, install the crystals and use it, unmodified, for the duration of the warantee period. If the radio is going to fail, experience has shown that such failures will usually occur within the first 90 days of use. Remember, that the 90 days starts the day it arrives in the mail, and does no good if the radio sits on a shelf.

We assume, at this point, that the 90-day warantee has expired and the radio remains alive and well. During this period, you should take the time to study the manual supplied by the manufacturer, to a point where you are not afraid to start poking around inside the radio. Particularly study the schematic, shown here in Fig. 12-1. You should be familiar with such details as the fact that the receiver crystals are mounted on the exciter board, that the radio is constructed in four major modules, the radio has only a deviation control but no transmit audio control, and so on.

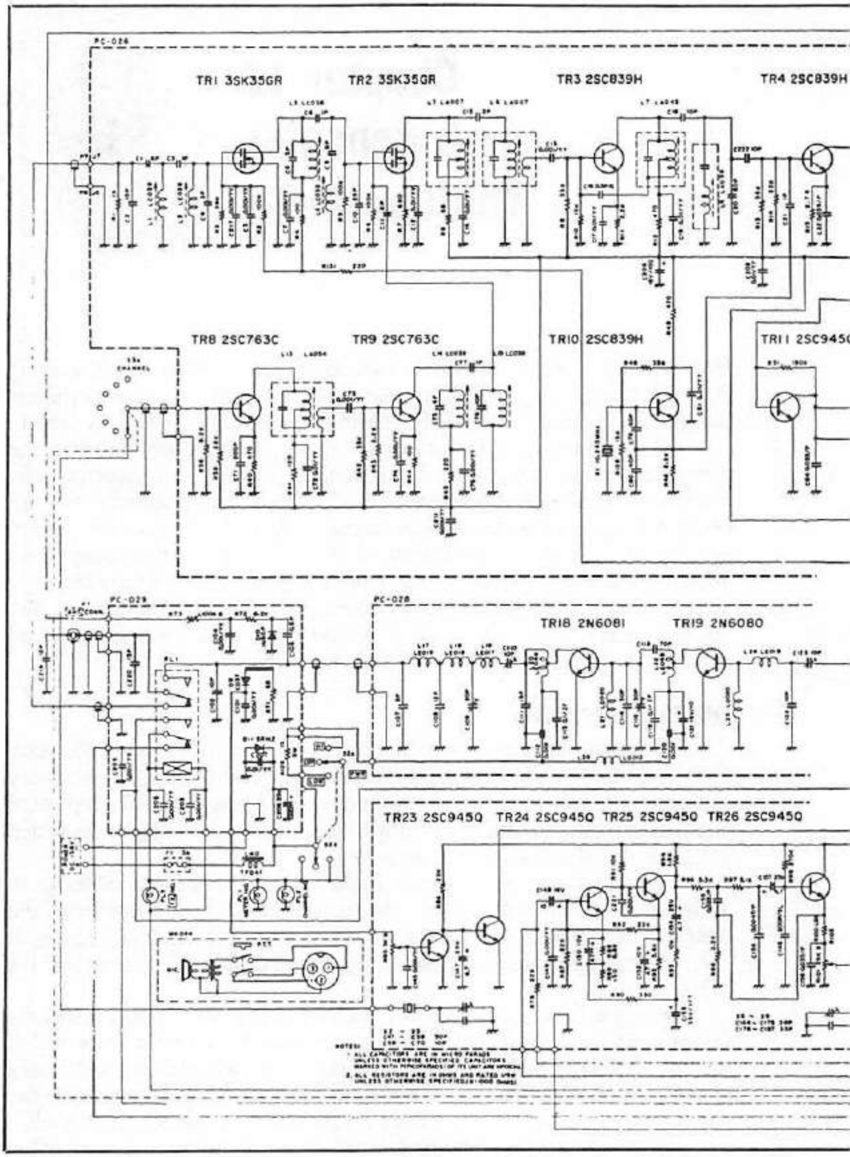
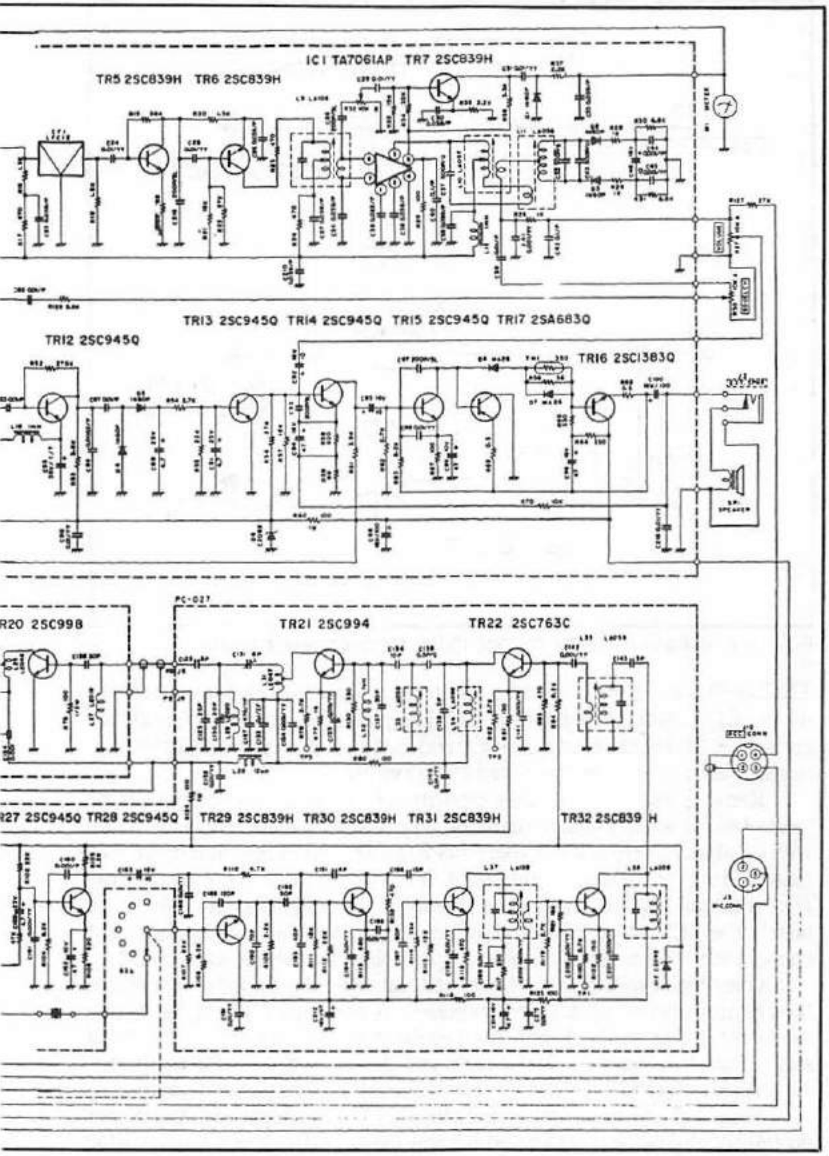


Fig. 12-1. Schematic diagram of the Clegg FM-27 220-MHz transceiver (Clegg of Communications).

Now comes the point of no return—you must take into your hands an almost-new radio and cut it up. I suggest, however, that prior to any major surgery, that you carefully draw a diagram of what wire goes where. For example, what receiver board connection goes to that green wire, and



where does it go? Does it go to the squelch-control wiper, the meter, or where? This sheet is only one piece of paper in what may end up as a 500 page, or more, system-documentation file.

Conversion to Duplex Base

Remove the receiver board from the radio, and mount it in a well-shielded enclousure. Run the RF lead through a connector such as a BNC,

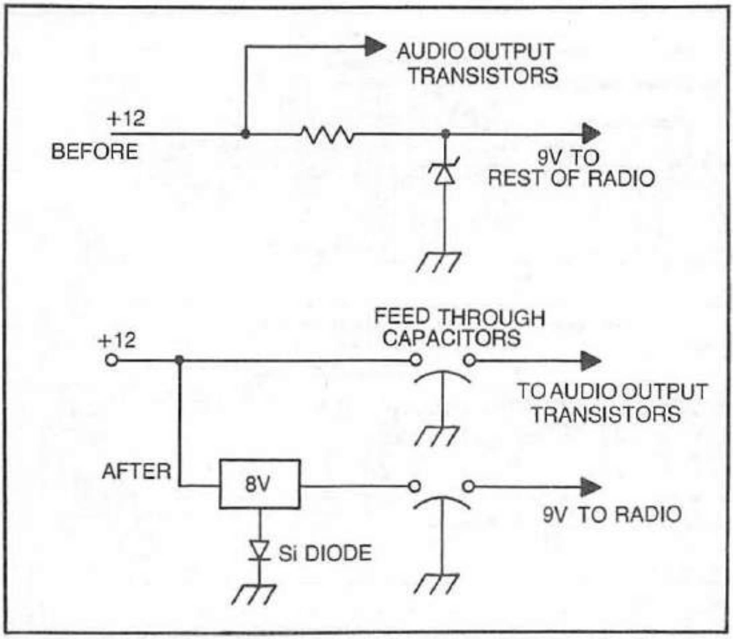


Fig. 12-2. Voltage regulator change in the receiver power supply.

TNC, or SO-239. Run everything else through bypass capacitors. I suggest tht the COR and CTS decoder (if used) be placed external to the receiver enclosure. Mount the receiver board and feedthroughs on the lid of the box, to allow easy access to the board for servicing.

Remove one of the trimmer capacitors from the receiver crystal bank located on the exciter board. Also remove the small padder that is in parallel with it. Manufacture a small board holding a crystal socket and these two caps, and wire it to the receiver board. It can be mounted in the rectangular area that surrounded the crystal switch in the original radio. Wire it to match the original circuit as shown in the radio's wiring diagram, and connect it to the original crystal-contact points on the receiver board.

One modification that has been made on several receivers is to replace the resistor-and-zener-diode 9V regulator circuit with a 3-terminal device as shown in Fig. 12-2. Mount the regulator outside the box, on a metal surface for heat sinking. Make sure you decouple the power to the receiver. See Fig. 12-3. This completes the basic receiver conversion.

Repeat the remove-and-install steps for the exciter board, but do not do the 9V-regulator modification for the exciter—the common regulator chips don't work in an RF environment. Wire the exciter board so as to use one crystal. Remove the PA assembly from the chassis, and mount it, along with the receiver and exciter, in a shielded enclosure. Decouple the power as in Fig. 12-4. Some builders use separate cabinets for the receiver and exciter-PA assemblies. Others put everything in one box; to each his own. I prefer the separate boxes—for extra shielding—although the single box takes up less space.

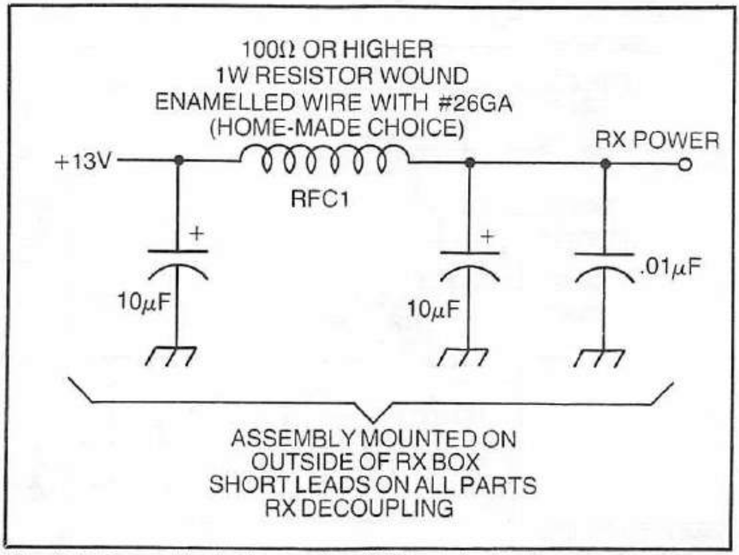


Fig. 12-3. Decoupling in the receiver 12-V supply circuit.

Remove the volume and squelch controls, the microphone jack, and the filter choke from the original radio. Mount the volume and squelch controls in the receiver box, and the microphone jack in the transmitter cabinet. Connect a speaker, an antenna, and a variable voltage supply to the receiver. While monitoring the current, gradually turn the voltage up to 12v. If you have a short, stop and find it. Check out the receiver thoroughly. Repeat the same steps with the transmitter, remembering that you no longer have a push-to-talk line to turn it on or off. Some people use a series-pass transistor, some don't like the voltage drop this generates, and use a relay. Don't try to get any more than 10 watts out of a Clegg transmitter used in a repeater. They will run longer, cleaner, and cooler at

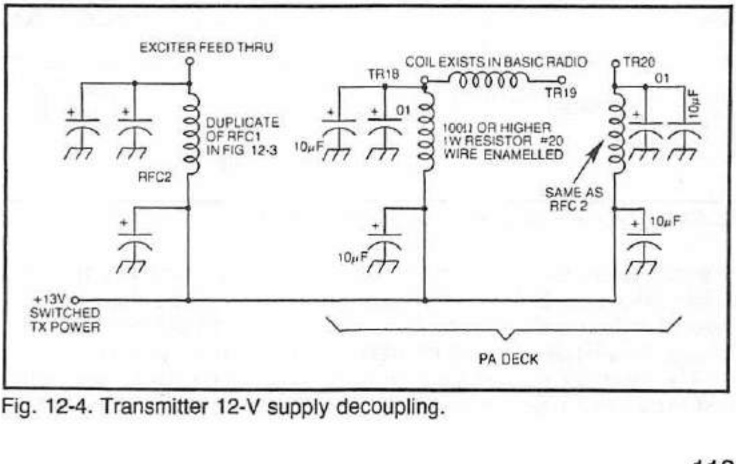


Fig. 12-4. Transmitter 12-V supply decoupling.

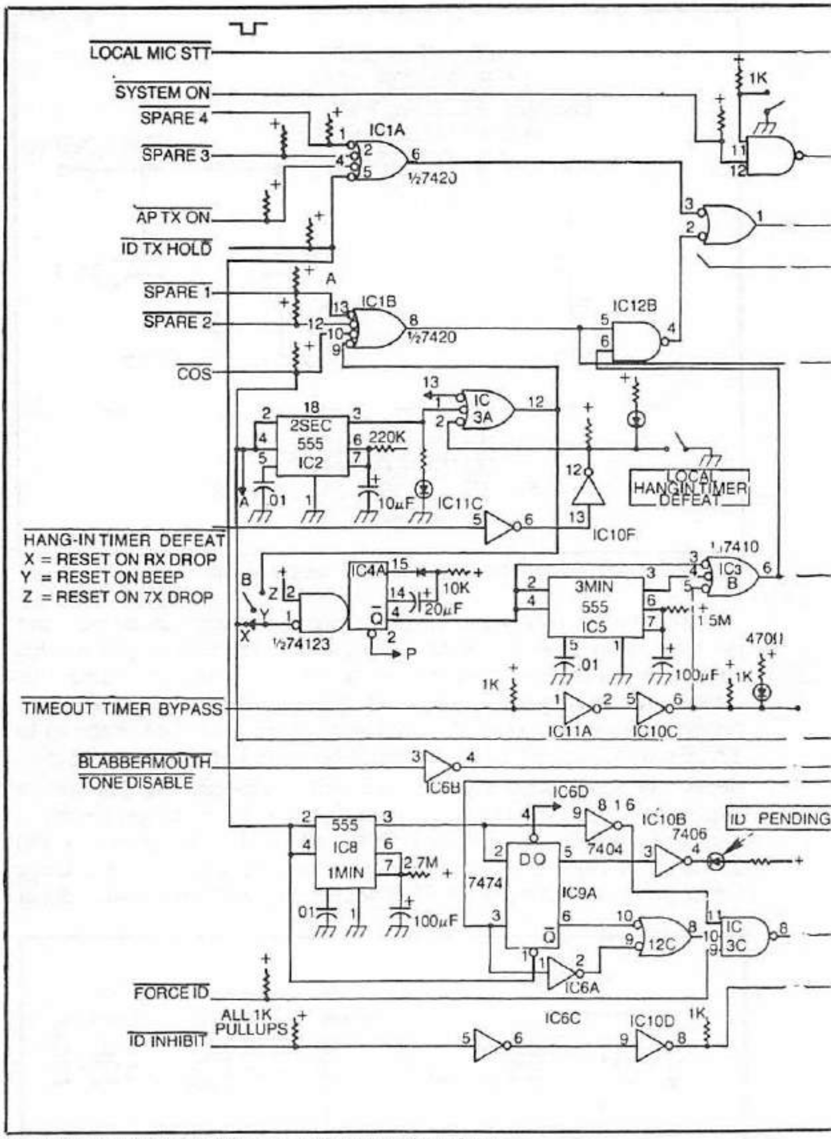
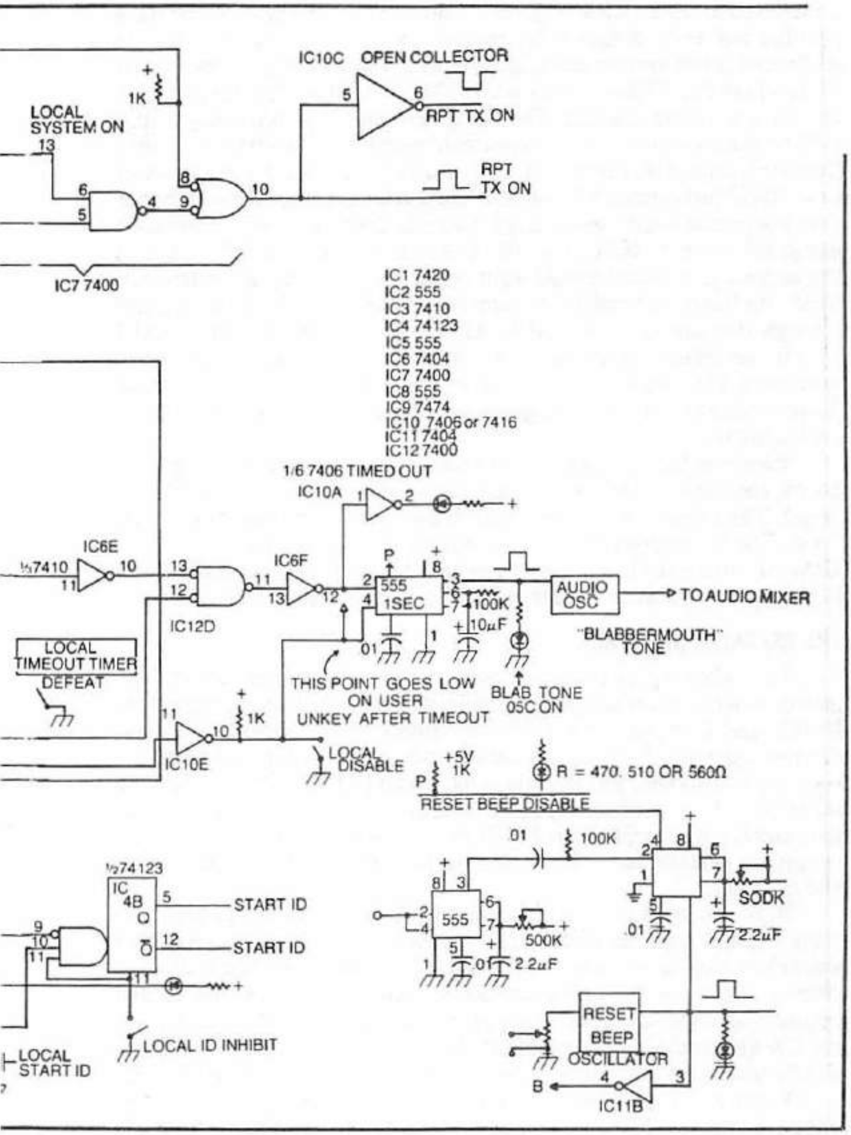


Fig. 12-5. The WA6ILQ repeater controller/interface.

10 watts. Some groups run the exciter continuously, and key the PA module, others run the PA continuously, and key the exciter. Check out the transmitter thoroughly, running it into a dummy load for at least 48 hours. Check it occasionally, looking for warm parts, or any drop in power.

If you were to hook two antennas to the device as you have it now, with crystals for a local repeater, you should have a working duplex base. This is



the foundation for any repeating system. The better this works, the better your repeater or remote will work.

The logic system from the CW Electronics unit is available, wired and tested, if you want to purchase it, or you can build your own using their diagrams, or the one shown in Fig. 12-5. This logic system was given to the author by a local group, and has everything. The time-out-timer reset can be selected to reset on RX drop, on TX drop, or on tone beep. Everything possible has been designed for remote control, remoted, and will be ineffective if left unconnected, and the local controls used. This logic is TTL, where the CW Electronics is CMOS. TTL will have less RF immunity and may need extra shielding. The logic has a feature which you may or may not like: If a user times out, the repeater transmitter drops off the air. When the user lets go of his mic button, an extra oscillator is turned on for a short time. This "Blabbermouth" tone tells him that he has timed out—far better than any person could—especially if it sounds like a raspberry. If you don't like it, just leave out IC6E, 12D, 6F, 10A, 6B, 10E, and the 555. Note that the autopatch transmitter-hold input is not timed, as the autopatch-logic used with this device had its own timers. SPARE1 and SPARE2 are timed through the timeout timer, while AP TX ON, SPARE3, and SPARE4 bypass the timeout timer. All of the inputs to this circuit are "on" when grounded. This technique has the advantage that if the circuit, or circuit board driving this one, is unplugged, the inputs of this circuit "pull" themselves inactive.

Whatever logic is used, I recommend that the logic be on one plug-in board, and the audio circuits, including any audio oscillators, on a different board. The reason for the split is that it prevents the possibilities of logic "clicks" being coupled into the audio, and audio being coupled into the logic. Granted, we are stretching the possibilities, but why ask for trouble when it is so easy to split your circuitry onto two boards during construction.

THE REPEATER INTERFACE

The following pages describe a complete repeater controller/interface/audio-mixer and power supply, designed by Warren Andreasen, N6WA, and featured in his C.W. Electronics Series 220-10 repeaters. Warren describes the basic interface as one that merely hooks up to the receiver's audio line, and plugs into the Clegg FM-76 accessory jack, to make the radio a 220-MHz repeater. Actually, it's a bit more complex than that, since, prior to making the FM-76 into a repeater you must first make it operate as a duplex base station. It must be free of desensitization, IMD, and other ills.

Here you will find something unusual: A manufacturer of a commercially available repeater offering his circuits to you. Warren believes that such ideas should be shared with those who wish to use them, and has offered to provide the necessary documentation on his circuits so that others could duplicate them. Included are schematics and board layouts for the CW Electronics repeater interface board. It can be used with the Clegg FM-76 boards, or the boards from either a Cobra 200 or Midland 13-509.

Further, for those who do not wish to build their own, either the interface board or the entire repeater package can be purchased from CW Electronics. Information about either the "Interface Board" or the complete "Repeater Package" can be obtained by contacting Warren at CW Electronics, P.O. Box 8306, Van Nuys, California 91409.

Receiver Board Modifications:

- Break the connection between the collector of transistor TR-13 and transistor TR-14 so that there is no connection whatever going to the collector pin of TR-13. From V_{cc} to this now open collector pin, place a 10K ohm, ½-watt resistor. This permits TR-13 to again function as a DC Squelch Control. From the junction of the collector and 10 K resistor, bring a lead to whatever output-input interface connector you have chosen. This is your squelch output tie-point.

- Locate the points on the receiver P/C board where the volume control leads are soldered. Locate both the hot lead from the discriminator and the ground return, then solder a piece of shielded audio wire to those points; braid to ground and center conductor to discriminator-audio out. The other end of this lead also goes to a connector on the shielded receiver compartment.
- Connect these leads with the Interface Board as shown in Fig. 12-6.

Exciter Board Modifications:

- Bring all necessary power, audio, and return leads to a connector of your choice.
- Route the antenna RF lead to a high quality BNC or TNC connector.
- Enclose the transmitter in a well-shielded box, as previously outlined.
- Interface to the repeater-interface board as shown in Fig. 12-6.

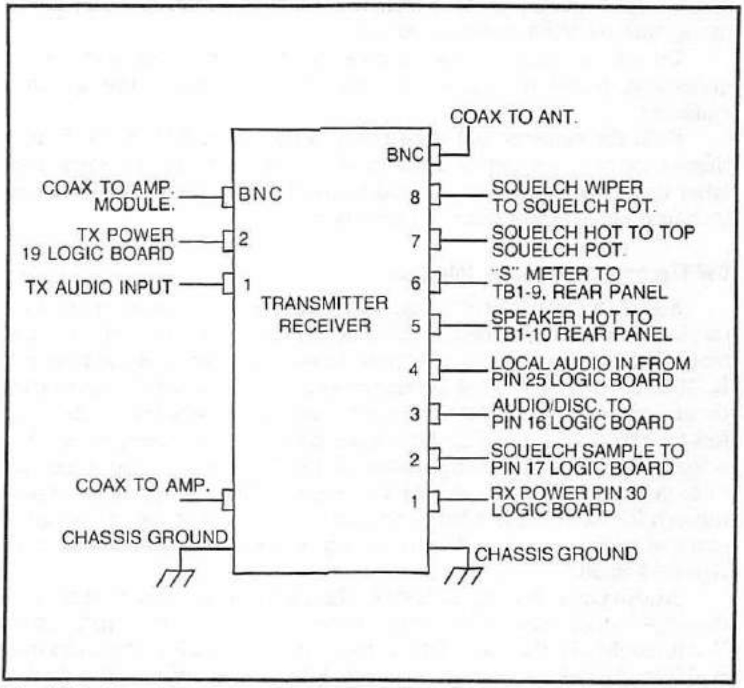

COAX TO ANT.
BNC
COAX TO AMP. MODULE.
BNC
TX POWER 19 LOGIC BOARD
2
TX AUDIO INPUT
1
TRANSMITTER RECEIVER
8
SQUELCH WIPER TO SQUELCH POT.
7
SQUELCH HOT TO TOP SQUELCH POT.
6
"S" METER TO TB1-9, REAR PANEL
5
SPEAKER HOT TO TB1-10 REAR PANEL
4
LOCAL AUDIO IN FROM PIN 25 LOGIC BOARD
3
AUDIO/DISC. TO PIN 16 LOGIC BOARD
2
SQUELCH SAMPLE TO PIN 17 LOGIC BOARD
1
RX POWER PIN 30 LOGIC BOARD
COAX TO AMP.
CHASSIS GROUND
CHASSIS GROUND

Fig. 12-6. Receiver and transmitter connections for interface with the CW Electronics controller.

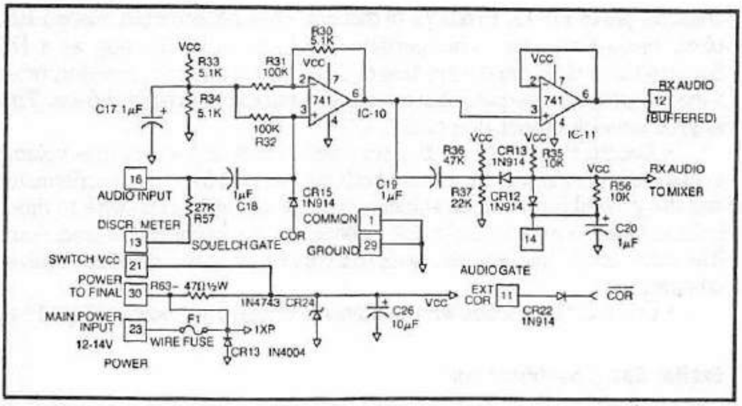


Fig. 12-7. Squelch gate, audio gate, and power decoupling of the CW Electronics interface.

General:

Never attempt to tune up a solid-state transmitter without the proper instrumentation and knowledge. Peaking for maximum output on a watt meter does not mean that all the RF is where you want it to be. In many cases, a spectrum analyzer will be necessary to ensure proper transmitter tuning with minimum spurious output.

Do not "re-align" an FM receiver by ear. If receiver alignment is necessary, follow the manufacturer's procedure, using the specified equipment.

Both the receiver and transmitter in the Clegg FM-76 are factory aligned for optimum performance prior to shipment, and no adjustment other than crystal frequency should be needed to achieve high-level performance either in personal or repeater use.

CW Electronics Repeater Interface

Squelch Gate. Refer to Fig. 12-7. Audio from the receiver comes in on pin 16 of the logic board. R57 sets the current for the discriminator meter for the normal 50-microampere zero-center meter. Audio goes into IC-10 on pin 3. If COR is low (carrier present), IC-10 is biased so as to allow the audio to pass on to the RX (receiver) audio buffer (which feeds the audio jack for external use), and the audio gate. If there is no carrier present, Vcc is fed to pin 3 of IC–10 through diode CR-15. This will cause the output (pin 6) to go hard high, and will hold it there, not allowing any audio to pass through IC-10. IC-11 is a buffer amplifier with a gain of one, allowing the external audio to be loaded quite heavily without loading or affecting the repeated audio.

Audio Gate. As long as diode CR12 is not pulled to ground at pin 14 of the edge connector, CR12 is forward biased. The main current path is from Vcc through R35, through CR13, through R37, to ground. The audio from IC-10 modulates the current through R37, which reflects the current changes to R35 and the voltage going the mixer. If pin 14 of the edge connector is pulled to ground, CR12 conducts, pulling the bottom of R35 to ground. In this condition, CR13 becomes back-biased and cannot conduct, and all audio is cut off at this point.

Power Supply. R63 and Zener diode CR24 are not for regulation. The purpose of this circuit is to protect the logic from voltage in excess of 13 volts. Any excess voltage will be limited and regulated by these components. Fuse F1 and diode CR23 protect against reverse voltage being applied.

Audio Mixer and Local Audio Pre-Amp. Refer to Fig. 12-8. IC-8 is a summing amplifier. Audio from each input is added together at pin 2 of IC-8, and come out on pin 6 as one signal. R4 1 sets the gain of this stage. R28 is the output-level adjustment which sets the amount of mixed audio to the transmitter. IC-7 is an amplifier with a fixed voltage gain of about 2. It boosts the mixed audio to a level necessary to drive the input to the speaker amplifier located in the receiver section. The gain of this stage sets the range of volume for the panel volume control and the audio monitor. R24 and 25 set the bias point for both IC-7 and 8, allowing them to amplify without distortion.

Xmit Key and Timer. Refer to Fig. 12-9. Any time a carrier is present, pin 2 of IC-9 is pulled low. This will cause pin 6 of IC-9 to go high, pushing current through R54, CR17, and into the base of Q8. This will cause Q8 to turn on, sinking current through R52, CR16, and the base of Q9. This will cause Q9 to turn on, supplying power from the collector of Q9 to the transmitter exciter, and causing the repeater to transmit a carrier. When the received carrier goes away, CR14 becomes back biased, allowing C16 to charge through R29 and R42. The setting of R29 sets the time for C16 to charge to a point where IC-9 will reverse states, allowing the transmitter to drop. This provides an adjustable tail which may be set to the length desired. If pin 20 of the edge connector is pulled low, CR18 conducts and will not allow Q8 to turn on, preventing the transmitter from transmitting.

Transmit Timer. The transmit timer (chopper) uses the 555 timer, IC-12. The time is determined by the charge time of C25. The charging

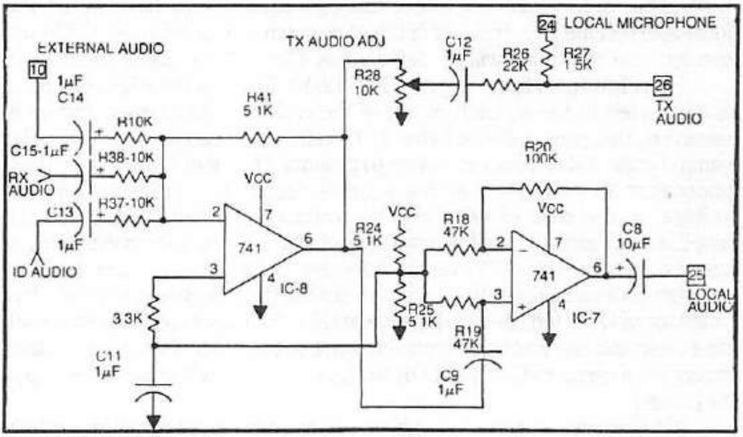


Fig. 12-8. CW Electronics audio mixer and local audio preamp circuits.

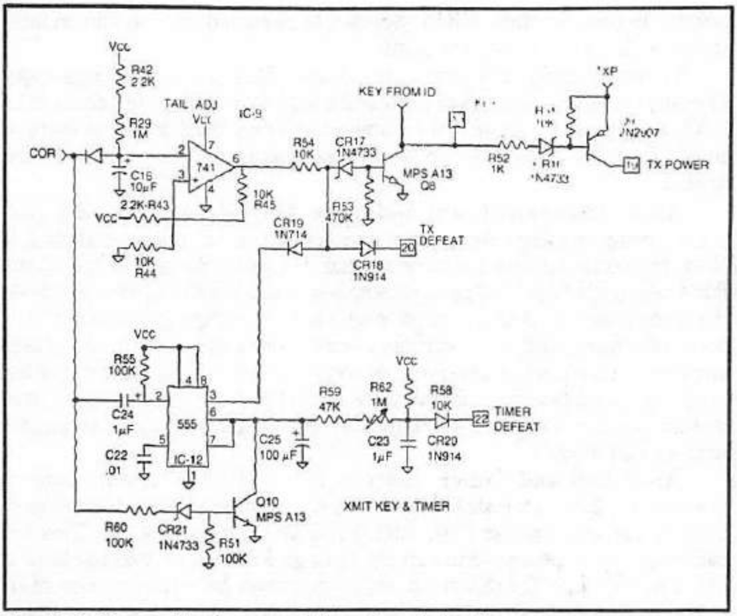


Fig. 12-9. Transmitter keyer and timer board circuits.

current is from Vcc through R58, R62, and R59. As long as no carrier is being received, Q10 is held on, which shorts the top of C25 to ground, not allowing it to charge. As long as it is in this state, pin 3 of IC-12 is high, which holds CR19 back biased. When a carrier is received, Q10 turns off and C25 starts to charge. When the charge on C25 reaches the proper level, the 555 switches and the output (pin 3) pulls to ground. This causes CR19 to conduct, removing the drive current from the base of Q8, and the transmitter drops off. The transmitter cannot be keyed until C25 is discharged by Q10. This timer does not affect the operation of the ID key, or the local-microphone key. If pin 22 of the edge connector is held low, CR20 will conduct and the timer will be defeated as C25 will be unable to charge.

Squelch Interface. Refer to Fig. 12-10. Pin 17 of the edge connector is connected to the squelch circuit of the receiver. Any time a carrier is received, this point will rise towards 12 volts. If no carrier is present, the sample point will remain very close to ground. The input to Q7 is very high impedance so as not to load the squelch circuit of the receiver. As the voltage on the base of Q7 rises, the voltage is placed on R50 and the amplified current is pulled from the base of Q6. This will in turn cause Q6 to turn on, placing Vcc (12V) on the collector of Q6. This current will flow through R48 and cause Q5 to turn on, pulling its collector to ground. The collector of Q5 is fed back to the base of Q6 to help lock Q6 on so there will be a clean and fast transition from one state to the other. Going in the other direction, a carrier will cause COR to rise to Vcc and will cause COR to pull to ground.

ID Control. A received carrier will cause the base of Q3 to pull low, turning off Q3. The collector of Q3 now goes high and places Vcc on pin 9 of

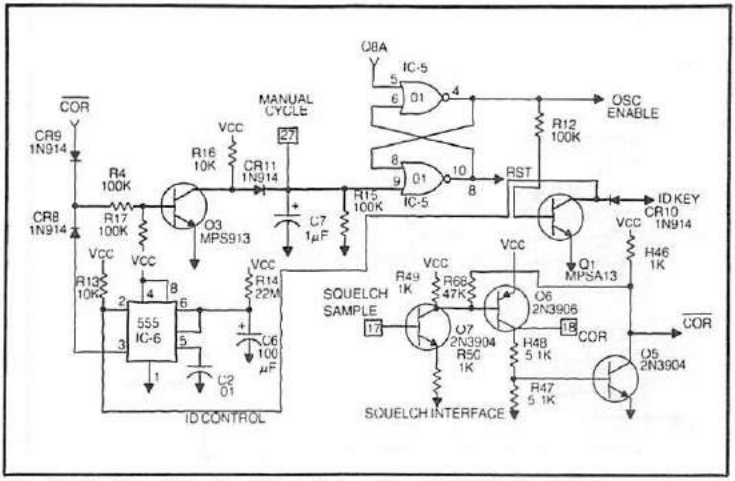


Fig. 12-10. Circuit for the ID control and squelch interface.

IC-5. This will cause the flip-flop formed by the two sections of IC-5 to set, with pin 10 going low and pin 4 going high. Ths action will disconnect the reset terminal from the IC counter IC-2 (Fig. 12-11), and also enable the clock oscillator to start running, stepping the memory-address counter. The OSC ENABLE terminal is also used to turn on Q1, making its collector to pull low. This action will trigger the ID timer (IC-6) causing its output (pin 3) to go low. This low is fed back to the base of Q3, which holds low until the timer resets, thus inhibiting any futher triggers and allowing only one ID per time period. The time period is determined by the charge time of C6 through R14.

ID Memory. Refer to Fig. 12-12. When there is a high on the input (pin 12) of IC-4, the oscillator formed by the two IC-4 circuits starts. The square-wave output is fed into the counter IC-2. The output of the counter stages is fed into the memory to form the address lines. As the counter counts, it scans the memory, providing data output at pin 13. This data will, in turn, enable the input (pin 1) of the other half of IC-4 which forms an audio oscillator with the two circuits, producing a tone. This tone is keyed off and on, and forms the ID. This tone is buffered by transistor Q4, and fed from the emitter potentiometer to the audio mixer. The decade counter IC-3 tries to count clock pulses also, but every time a tone-bit is provided by the memory, it resets the counter to zero. Whenever ten clock pulses occur without a tone bit resetting the counter, the counter will reach count 10, and this will cause the control flip-flop in Fig. 12-11 to be reset, stopping everything and resetting the ID circuitry. In the unlikely event the program is so long that there is not enough memory for 10 left-over bits, the Q8 output of counter IC-2 will cause this reset to occur. C4 and R3 form a short pulse which is used to "write enable" the memory during programming. The cross-coupled gates of IC-5 form a debouncer for the step switch so that, during programming, the counters will step only one step-per-push of the step push button. Refer to Figs. 12-13 through 12-15 and Table 12-1 for various building guides and diagrams.

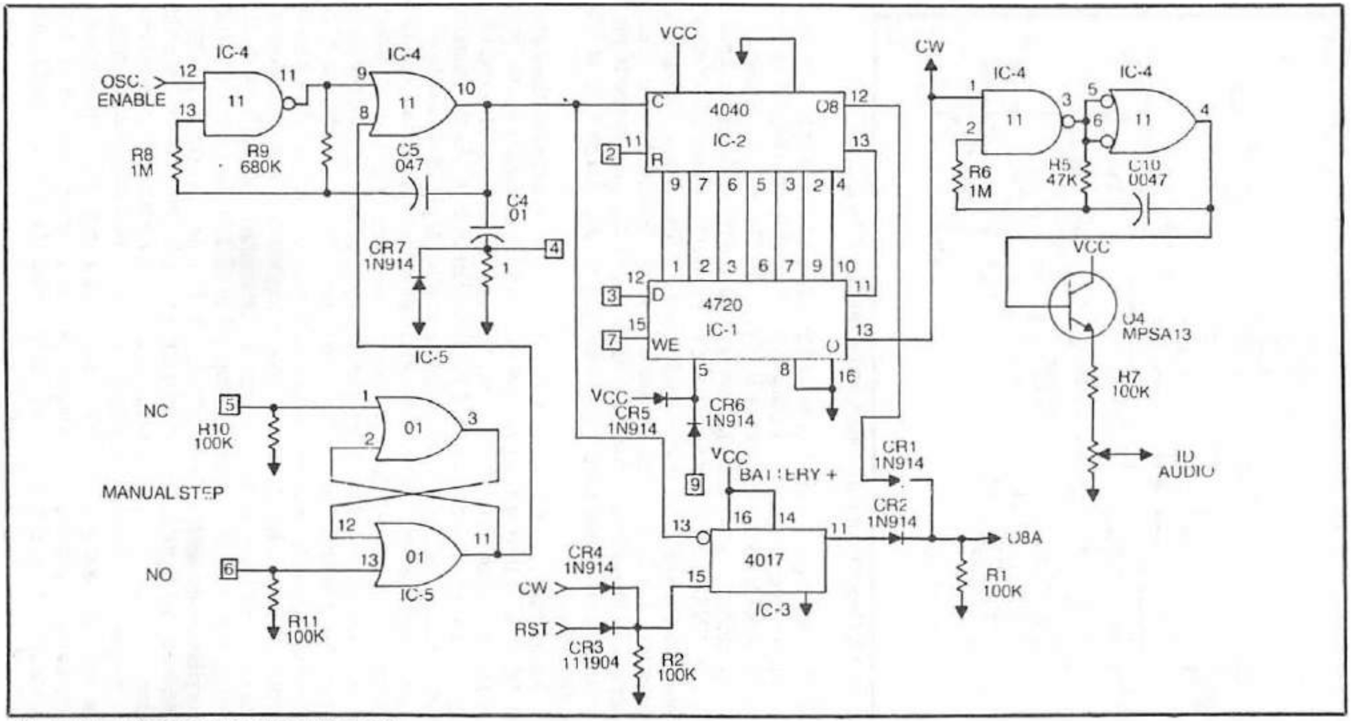


Fig. 12-11. ID memory and control circuit.

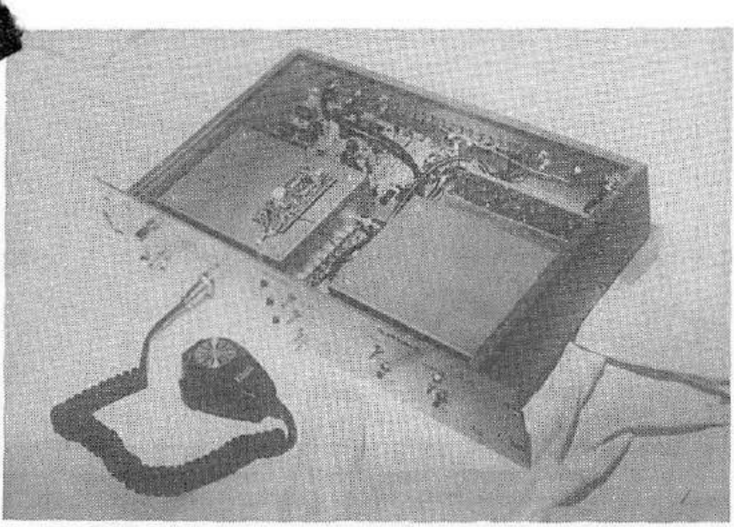


Fig. 12-12. The CW Electronics repeater package (courtesy of CW Electronics).

ID Programming. If you wish to first erase the contents of the entire memory, place the program switch in the PROGRAM position and the tone/space switch in the TONE position, then push the cycle button. This action will load the entire memory full of ones (tone). Next, toggle the program switch to normal and back to program. Note that this toggle action is necessary after each program cycle, as the ID will not cycle unless this action is taken. Now, with the tone/space switch in the SPACE position, hit CYCLE again. When the cycle is complete, the memory should be entirely blank. To enter a new ID, place the program switch in the PROGRAM position (toggle first if necessary), and place 5 spaces in the memory by

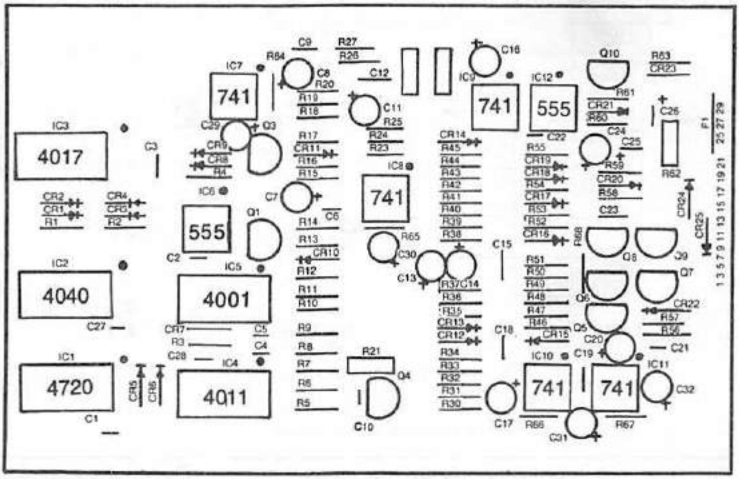
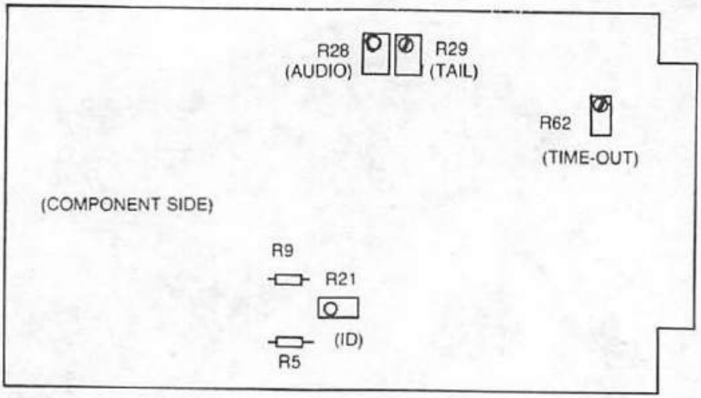


Fig. 12-13. Parts placement guide for the CW Electronics interface.



R28: TRANSMIT AUDIO DRIVE ADJUSTMENT. CLOCKWISE TO INCREASE.
R29: CARRIER TAIL LENGTH. COUNTER-CLOCKWISE TO INCREASE.
R21: IDENTIFIER AUDIO LEVEL. COUNTER-CLOCKWISE TO INCREASE.
R62: TIME-OUT TIMER LENGTH. COUNTER-CLOCKWISE TO INCREASE.

NOTE: ID PITCH IS CONTROLLED BY FIXED RESISTOR R5. INCREASE VALUE TO LOWER PITCH. THE ID SPEED IS CONTROLLED BY FIXED VALUE RESISTOR R9. INCREASE VALUE TO SLOW SPEED.

Fig. 12-14. Location of important controls on the interface card.

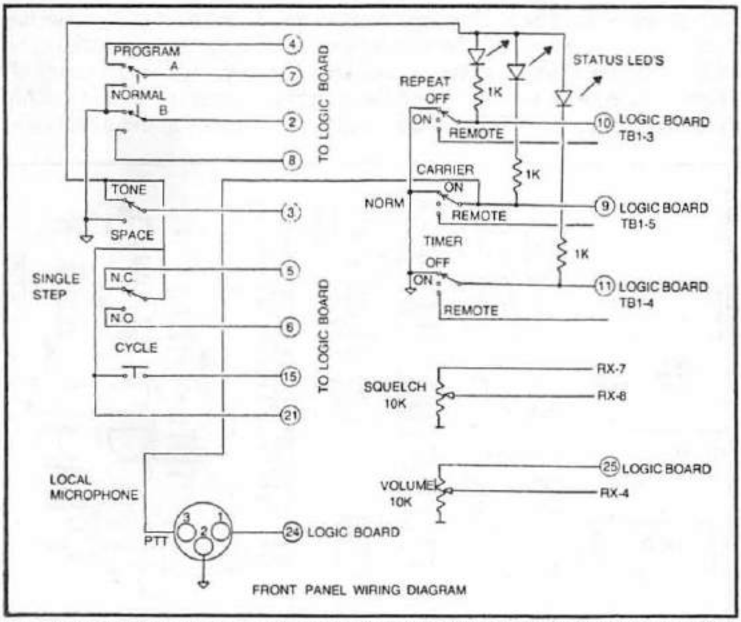
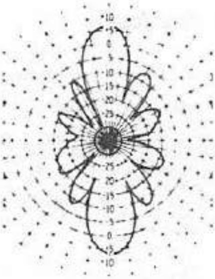


Fig. 12-15. Wiring diagram of the front panel of the CW Electronics repeater interface and control.

Table 12-1. Logic board edge-connector pin identification.

PIN	SIGNAL	GOES TO
1-	COMMON GROUND	CHASSIS GROUND
2-	MEMORY RESET	PROGRAM SWITCH (B). COMMON. FRONT PANEL
3-	ID MEM. DATA IN	COMMON TONE/SPACE SWITCH. FRONT PANEL
4-	ID MEM. WRITE EN	PROGRAM POS. PROG. SWITCH (A). FRONT PANEL
5-	MAN. STEP PB. NC	NC. CONTACT. MAN. STEP PUSH BUT. FRONT PANEL
6-	MAN. STEP PB. NO	NO. CONTACT. MAN. STEP PUSH BUT. FRONT PANEL
7-	ID MEM. WRITE EN	PROGRAM SWITCH (A). COMMON. FRONT PANEL
8-	RESET (RST)	PROGRAM SWITCH (B). NORMAL POS. FRONT PANEL
9-	9 VOLTS POS. IN.	PLUS SIDE OF KEEP-ALIVE BATTERY FOR ID MEM
10-	EXT. AUDIO INPUT	TX AUDIO JACK "HOT" ON REAR PANEL
11-	EXTERNAL COR SENSE	TB1-6. REAR PANEL
12-	BUFFERED RX AUDIO	OUTPUT TO RX AUDIO. "HOT." JACK ON REAR PANEL
13-	DISCRIMINATOR	METER OUTPUT TO TB1-8. REAR PANEL
14-	AUDIO GATE	TB1-7. REAR PANEL
15-	CARRIER KEY	TB1-5 REAR PANEL AND COMMON. CARRIER SWITCH
16-	RX AUDIO	RECEIVER BOX TERMINAL 3
17-	SOUELCH SAMPLE	RECEIVER BOX TERMINAL 2
18-	COR OUTPUT	NOT USED (12 VOLTS WHEN CARRIER RECEIVED)
19-	SWITCHED TX POWER	TRANSMITTER BOX. TERMINAL 2
20-	REPEAT DEFEAT	COMMON. REPEAT SWITCH. FRONT PANEL
21-	12 VOLTS TO SWITCHES/	SAFE POWER. TO SWITCHES ON FRONT PANEL
22-	TIMER DEFEAT	COMMON. TIMER SWITCH. FRONT PANEL
23-	12 VOLTS	UNFUSED POWER INPUT FROM TB1-1. REAR PANEL
24-	LOCAL MICROPHONE	FROM PIN 1. MICROPHONE CONNECTOR FRONT PANEL
25-	MIXED AUDIO OUT	LOCAN MONITOR AUDIO. TO RECEIVER TERMINAL 4
26-	MIXED AUDIO	TRANSMITTER BOX. TERMINAL 1
27-	ID MAN. CYCLE	FRONT PANEL CYCLE PUSHBUTTON
28-	SPARE	PIN NOT USED
29-	COMMON GROUND	CHASSIS GROUND
30-	FUSED POWER	ALL POWER POINTS IN REPEATER (RX & PWR AMP)

stepping 5 steps with the tone/space switch in the SPACE position. This will allow time for the repeater to "come up to speed" before the ID starts; it is not necessary but is good practice. Never place a tone in the first step, as it will place a continuous tone on the carrier when it is keyed. After deciding what code is to be entered, key it into memory by stepping in three steps of TONE for a cash, and one step of SPACE for a break between elements of a letter or number. A dot would consist of one step of TONE followed by one step of SPACE. The inter-letter spacing would be 3 steps of SPACE, and inter-word spacing would be 5 steps of SPACE. There are 256 steps of memory available and a normal ID uses less than half of that, so there is plenty of memory to do whatever is desired. Using a *dot* to be a *space*, and a *dash* to be a *tone*, a sample program with the word "TEST" would look like this! . . . . . - - - . . . - . . . - . - . - . . . - - - . . . .



Chapter 13

Cleaning Up The 220 Transmitter and Receiver

The Clegg FM-76 transmitter is an excellent, 12-channel, broadband transmitter, and therein lies the biggest problem with adapting it for repeater use.

The typical radio that "Joe Ham" uses will put out 10 to 12 watts of useful power from 222.0 to 224.98 MHz, and will hear adequately over the same range. This broadband characteristic passes shot and thermal noise, which can be a detriment when you are trying to run a sensitive receiver in the same rack. Noise is broadband energy similar to a spark—but lower in power, and continuous.

Let's look at numbers for a minute. Let's say that we have 10 watts out, and all spurious and noise 60 dB down. A little math says that 60 dB down from 10 watts is 10 6μ W. If we figure that $E = \sqrt{P/}R$, 10 μW into 50 ohms is 447 μV. That much transmitter noise wandering around inside a rack is going to capture your receiver from anything but a radio in the same room.

This gets even worse if there is a power amplifier in the repeater. Most of the available amplifiers are manufacturer-modified mobile (read "broadband") units, mounted on a rack panel, with a big heat sink and maybe a fan. Let's say the amp is 100 watts, for easy math: 60dB down from 100 watts is 100 μW, which is 1.414 mV. No, not μV, mV—millivolts!

There are two ways to cure the problem: rebuild the transmitter and cure the cause; or shield and filter the transmitter and cure the effect. Unfortunately, most groups have taken the latter choice. Some have changed every bypass and coupling capacitor to high-grade silvermicas, with values calculated to optimize their effectiveness. Others have juggled L-C ratio in the exciter board, and removed the overcoupling that broadbands the unit for mobile use. Others have designed tuned-line filters that are inserted between the exciter and PA deck, and between the preamp and the receiver.

One trick, if you have access to a good spectrum analyzer, is to tune the exciter for maximum clean power, then add the PA deck and repeat the process, then the external amplifier and repeat the tuning. Take whatever *clean* power you can get, and then amplify that.

Sometimes it takes just plain hunches, magic, and prayer. Here are the descriptions for two different systems:

1: Clegg exciter with redone bypass capacitors (silver micas, double the original value, didn't bother calculating each one), in a die-cast box with

TNC RF connector. The power amplifier is in it's own die-cast box with TNC fittings, feeding a tuned-line filter to the transmitter port of a Phelps-Dodge duplexer. All interconnecting RF cable was good, new, double-shielded mil-spec coax.

2: Cobra exciter updated to current production parts and values, with a DC-power decoupling network feeding it, the exciter was tuned with an analyzer and fitted into a die-cast box. The PA deck had its own decoupling network and was fed through a tuned-line filter from the exciter. Double-shielded coax was used throughout.

Your system may not need all of the modifications mentioned above, but consider the following points:

In the L.A. area, most systems are located in RF saturated areas—Mt. Wilson has an estimated 1 -5 megawatts ERP in a 4-square-mile area, and some people claim as high as 1 gigawatt ERP. No matter what set of numbers you hear, when a Simpson 260 is set on the 2.5 ACV scale and, with no probes inserted, reads half when held at arms length, that's a lot of power in the air! In conditions like that, double-shielded coax is a must.

Most sites are on tops of mountains or large buildings. It is difficult to get two sites on the same mountain, or in the same area. Split-site construction means different receiver transmitter coverage, which is annoying to say the least. For this reason, about 95 percent of the systems in the L.A. area are single-site.

Things aren't going to get any better. You are going to build a system, so you might as well do the best job you can and have to do it only once. If you cut corners on the initial construction, you might save 5 to 10 man-hours now, but what will it cost you in reduced performance and a trip every 2 weeks to fiddle with the system? Maybe a year or two from now someone is going to install a 330-watt paging system next to your rack, and if you don't have good, tight shielding in your equipment, a multiplier spur just might mix with one of your multiplier outputs, and land on your input, or maybe on one of your I-F channels. Even if it isn't a huge paging system that is installed, the RF Level will get worst at any site, given enough time.

The die-cast boxes are not vital, but good shielding is. The author has shielded receivers and exciters by building boxes out of copper-clad circuit board, soldered (very carefully) with a propane torch or a large iron, and of solder. The completed box is then filled with rubbing alcohol. If the box will hold alcohol with no leaks, it will probably hold RF. Alcohol is suggested for the following reasons: It doesn't cause corrosion. If a drop of water were to remain in the box, it would result in green glop all over your boards in short order. It tends to be "wetter" than water, and can get through a smaller hole and show up a smaller leak. The alcohol, along with a stiff toothbrush, will remove all traces of flux, and make the box look shiny clean. There are better flux removers, but alcohol is readily available at most drugstores.

The only problem with PC Board boxes is their limited access to the unit for peaking and tweaking.

WHAT FREQUENCY IS THE POWER ON?

The average user, while peaking up his radio and watching the front panel meter, does not realize just what he is doing. The meter is reading power, sure, but the person doesn't realize that the meter reads useful power, spurs, and noise, and sums them. In other words, wattmeter reads power on all frequencies simultaneously, and a lightbulb dummy load the front-panel meter, is worse because it isn't linear or calibrated. You can't tell how much of what is where without a spectrum analyzer.

PULLING THE BIRDIES OUT OF THE RECEIVER

If you hear signals in your FM-76 from frequencies other than the one stamped on your crystal, it is probably due to the design of the receiver local oscillator. Walt Diem, WA6PEA, chased the problem while building the repeaters for the Jet Propulsion Labs Radio Club, W6VIO/WR6APQ/WR6APR/WR6APS, and his solution is presented below.

These radios use a third-overtone crystal in the receiver local oscillator. However some crystals can oscillate at two or more frequencies simultaneously in the stock circuit. The third harmonic of the unwanted frequency is approximately 60 KHz away from the desired frequency. As an example, when listening to 224.04 you might hear 223.98 when they come on.

The solution is to eliminate the undesired oscillation at approximately 17.75 mc with a series trap between the base of the oscillator transistor and ground. Acquire one 8.2 μH choke and one 10 pF silver-mica capacitor. Hook these two parts in series, leaving only ¼ inch of lead between them. Connect the assembly in parallel with R38(i.e. base of TR8 to ground. This is best done on the foil side of the board.

You may want to install this change, even if you haven't had this problem. Perhaps you were out of range of the 60kHz-away machines. Once you drive into an area where the two service areas overlap, your radio may be useless! Or the next crystal you buy may start double-oscillating.

The modified circuit is shown in Fig. 13-1.

Another useful change in the receiver is to add a 10.7 mc crystal filter for increased selectivity. Piezo Technology in Orlando, Florida, and Crystal Devices, Inc. in Phoenix, Arizona, make good ones and the addition can get rid of a lot of problems. The installation is fairly easy, but time consuming. A

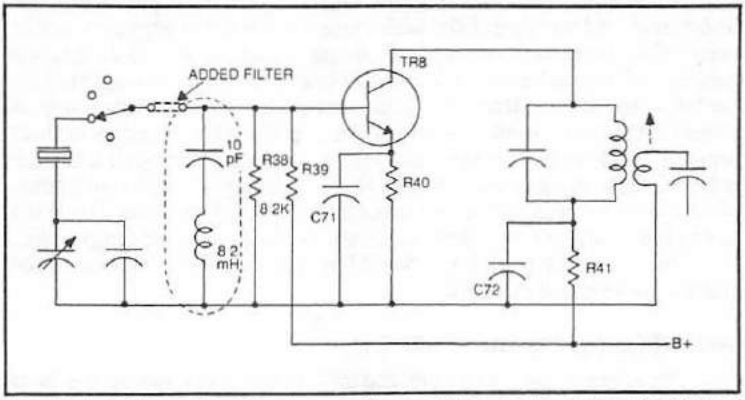


Fig. 13-1. A filter added to clean up the oscillator in the Clegg FM-76 local oscillator.

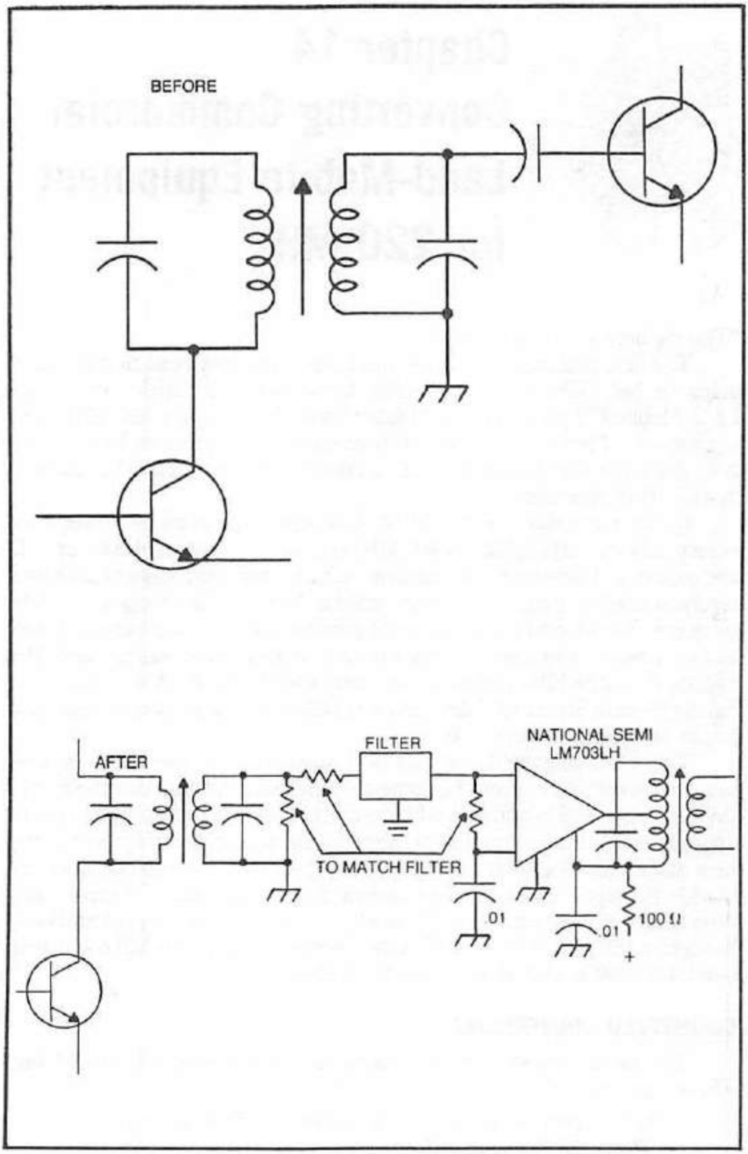
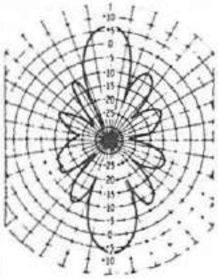


Fig. 13-2. Receiver selectivity can be improved by adding a crystal filter, and an extra amplifier to make up for the insertion loss, to the I-F amplifier stages.

high I-F transformer is carefully removed, and a small board is made up containing the original transformer, the filter, and an I-F Amplifier (to recover the gain lost due to the insertion loss of the filter), and another transformer from a narrow-band 0.7 I-F strip. See Fig. 13-2.



Chapter 14

Converting Commercial Land-Mobile Equipment for 220 MHz

"The rig here is a Motorola".

The first reaction most hams will have when they read that is either going to be: "What? . . . or, from those unfamiliar with commercial Land-Mobile FM product lines: "I didn't know that company built 220-MHz equipment" They're right—no commercial manufacturer of land-mobile gear does, but that does not mean that their equipment cannot be made to work in that spectrum.

In the early days of 220 MHz, little gear was available other than scarce military surplus (225 to 400 MHz is used for mostly AM both aircraft and military). There were no technical manuals, and what was available was rarely a complete unit, let alone operational. None of that stopped the early pioneers. They found ways to use the surplus military equipment as parts, and somehow made usable stations from it. In fact, what was probably the nations first 220-MHz Amateur repeater, the WA6LNU AM repeater on Saddle Peak in Southern California, was built from surplus equipment, and began service in the mid 1960's.

The FCC upgraded the technical standards for the two-way land mobile FM communications equipment about the same time that the first of the solid-state and hybrid radios hit the market. Many companies decided to upgrade rather than convert all of their existing tube-type equipment to the new standards. Suddenly, a lot of older equipment entered the Amateur market through various sources—much of it bargain priced. People could now afford to experiment. Eventually, some of the experimentation brought a number of these radios into service on the 220-MHz Amateur band, and that's what this section is all about.

COMMERCIAL CONVERSIONS:

The most common conversions of surplus Commercial Land Mobile FM equipment seem to be:

- G.E. Progress Line UHF Receiver and Transmitter
- Motorola Sensicon "A" Receiver.
- Motorola "A" series Transmitters (30 and 60 watt)
- Motorola Sensicon "G" Receiver

General Conversion Techniques:

High-Band Transmitter. Locate a radio with driver and final tubes that are capable of producing useful power at 220 MHz, and which has a 75

MHz to 150 MHz doubler stage as part of it's design. Convert this doubler to a tripler that provides 225-MHz output. Rebuild the driver and final-amplifier stages so as to tune the 220 to 225 MHz Amateur band.

If you already possess a transmitter for high-band with a final-amplifier tube that is not designed to perform on 220 MHz, don't throw it away. Research may show that another tube can be directly interchanged, and thus yield good performance. An example of this is the type 829B final amplifier tube found in the 60-watt Motorola "A" transmitter. A type 5894 will plug directly into the 829B socket and perform well on 220 MHz. (However, the plate circuitry will have to be changed.)

One caution. Do not use a wideband transmitter. Even a narrowband transmitter will need to have it's deviation lowered due to the extra multiplication factor. Make sure it has the splatter choke in it.

High-Band Receiver. There are no hard and fast answers here due to the variety of I-F frequencies, the local-oscillator crystal-frequency ranges, and local oscillator multiplication chains. A general set of rules to follow might be:

- Use as high an IF as practical. This moves the image as far away as possible. Here, the G.E. UHF Prog Line has a definite advantage—its first I-F is 48 MHz.
- Depending on your receiver's first I-F, try not to put the image frequency in a VHF TV Channel which is active in your area. Why go looking for problems?
- Choose your receiver and transmitter carefully. Know what you are using. You don't want to discover that one of your transmitter multiplier products falls in your receiver I-F Passband.
- Always use a narrowband receiver.

There are some cases where the second rule can be violated, depending on the performance of your receiver's front end, and its overall dynamic range. For instance, both the 220-MHz converted Motorola Sensicon "A" and "G" receivers have image frequencies in the TV band, with no adverse effects, if the conversion is done properly and carefully.

High-UHF Transmitter. This is fairly obvious. Remove a doubler stage and rebuild all following stages. Then, turn up the deviation level to double what it was before, to take into account the lost doubler stage. The unique structure of the 75 to 225 MHz tripler-plate resonator in the G.E. Prog 4ET24 transmitter makes it one of the easiest conversions around. It will putout 20 - 30 watts of clean RF. This level is sufficient to drive a 4CX250 final to full rated power, and then some.

UHF Receivers. As with High-Band receivers, here, too, there are many variables. They are worse, due to the wider range of I-F's and multiplier combinations. The same four rules for high-band. A good continuous duty, 8 watts in, 250-300 watts out, 4CX250B amplifier was published in *QST* for May 1969, pgs. 21-27.

UHF Receivers. As with High-Band receivers, here, too, there are many variables. They are worse, due to the wider range of I-F's and multiplier combinations. The same four rules for high-band receivers apply here as well.

Crystal Ovens. Use a crystal oven in any receiver or transmitter designed to accept one, especially if it is to be used in a repeater or inter-link. True, it will require some extra heater current, but the increased stability is worth it. The last thing you want to do is find yourself chasing your links across the spectrum when the first freeze or heatwave hits your site.

Don't use an oven-type crystal without an oven, or vice versa, if you want stability. If you look at a crystal temperature-versus-stability chart, you will note a large flat area wherein the frequency shift is minimal for a large temperature variation. The frequency swing per degree of temperature shift rises rapidly once you leave that choice area. For reference, this area is centered around 25 ° C for non-oven crystals and 80°C for crystals operated in an oven.

GE PROGRESS LINE CONVERSION

The following information was donated by K6IG, and is reprinted here through the courtesy of the Crestline Amateur Repeater Organization, who sponsor the WR6ACJ 146.25/.85 and 223.26/224.86 MHz repeaters in the Los Angeles area. Some information beyond what is presented in the article:

- The UHF 4ER26 receiver, tells you by it's suffix letter if the receiver is narrowband (A) or wideband (B). Factory-built narrowband radio's are scarce, but there are a couple of tricks that can be done. All of the narrowband-determining circuits are contained in the single 6-ccil, low-I-F can. This can is identical in both the Pre-Prog and Prog UHF radio's, and the high-band Prog-line as well.

The differences are detailed in the high-band Prog books. True, the wideband coil assembly can be narrowbanded, but it is much easier to cannibalize an I-F can from a narrowband receiver. Another trick, if you have only a wideband UHF Prog receiver, is to use it's front end as a converter, feeding a 48-MHz narrowband receiver. These are more common than narrowband UHF receivers. This system will hear far better than a "barefoot" Prog receiver.

Remember, you must do a full realignment preferably with a sweep generator, if you make any changes in the low-I-F circuits.

Some more Prog identification notes: The "1" (single frequency) and "11" (2 frequency) units are optional oven AFC Controlled types, and the "2" (single frequency) and "12" (2 frequency) are oven-crystal type, non-AFC receivers. Types "2" and "12" must use an oven. If you happen to have a type "1" or "11" and it is suggested that you disable the AFC, purchase an oven-collated crystal of good quality, and use it in an oven.

The design of the UHF Prog front end is somewhat unique in that it uses a cavity for selectivity and antenna tuning. Since this front end selectivity is the first item removed or bypassed in the 220-MHz conversion, you now have a receiver that will hear anything, once connected directly to an antenna. It is recommended that you use at least one good quality, high-Q cavity between the converted receiver and the antenna. In lieu of this, you might construct a helical resonator to restore front-end selectivity, use a crystal-filter front-end with a preamp, or use the receiver only with a duplexer-type antenna system.

The 4ET24 Transmitter

The narrowband characteristic is not as important in the transmitter, because, by removing a doubler to convert the transmitter from 450 to 220, the deviation has been reduced. Therefore, a ±15 kHz wideband transmitter is now a ±7.5 kHz unit, and can be lowered to ± 5 kHz easily without any component changes.

One unfortunate trait of the Prog transmitter is that when either the driver or the final tube goes, it tends to take the other with it. This wouldn't be so bad except that the 6907 tubes are, at this writing, in the $60 price class. Commercial pull-out tubes are getting scarce because these radios are being retired, and the bad-at-450-but-good-at-220 tubes can't be found any more. Many times, the used radios that do show up at ham swap meets are bought just for the tubes.

The Power Supplies

Power supplies for the progress line radios come in two basic types—the continuous-duty types and the intermittent-duty types. The continuous-duty units are the 4EP3 series for the receivers, and the 4EP4 series for the transmitters. These units have a mobile-sized strip hole in the rack-mount chassis. Be careful with the 4EP4—this supply fed everything from a 12W UHF strip to a 100W low-band strip, and the high-voltage jumpers must be set to the right voltage. The suffix letters and numbers on the 4EP3 and the 4EP4 are option identifiers for such things as COR, cathode follower, or CG deck.

The intermittent-duty units are frequently called desk top supplies, because the most common application was the desktop base radios.

This supply will *not* handle the transmitter for continuous duty (ie, repeater duty)! The easy way to spot this supply is that it is the same size as a receiver or transmitter strip.

One last note—make sure that the heater wiring for the strip matches the supply. It's embarassing when you hook a 6-V strip to a supply wired for 12 V!

MOTOROLA SENSICON A RECEIVER CONVERSION

The Motorola Sensicon "A" highband receiver has probably been responsible for more successful Amateur 2-meter repeaters than anything before or after. Though obsolete when compared with today's modern solid-state receivers, it is still a prize sought after by many FM enthusiasts.

Why this following? Simply, the Sensicon "A" is one of the finest receivers ever designed, and most FMers know it. Models for both lowband and highband were manufactured. Most factory units were wideband, though many were converted to narrowband operation in the field. The author has found that it is not unusual for a lowband unit tuned up on 6 meters to exhibit 0.07 μ for 20dB quieting. This was hard to believe until three converted receivers in a row produced this type of sensitivity after realignment on three different generators (one of the generators fresh from calibration). What can you say?

For repeater operation, you will want a narrowbanded, highband unit complete with a rack-mount, bottom plate, and shielding kit. Note: There is a small shield plate over an I-F stage on the underside, in about the middle of the strip. If this cover plate is missing, the receiver I-F will oscillate. Try to find a receiver with this shield plate in place. In lieu of this, a shield plate can be made from heavy copper foil, or a piece of single-clad PC board, to fit the area. Do not attempt to operate the receiver without this shield in place.

Before you begin the 220-MHz conversion process or installation of the receiver as a 2-meter repeater receiver, bench-check it to be sure it works properly. There is nothing more embarassing than installing or converting a dead receiver. If you already have commercial-band receive crystal, use it for bench checking. When you get the receiver playing, run the tubes through a good transconductance, or mutual conductance, tube checker. Avoid the tube checkers you see in drug, hardware, and electronics stores. They check only for shorts, gas, and cathode emission. Test any new tubes as well—prior to paying for them. New tubes, out of the box, have been known to be stone dead!

The receiver need only be aligned to the desired 2-meter operating frequency in accordance with the instructions in its service manual to become operational. The same holds true for the lowband version of this receiver in relation to operation on 6 meters. For operation on 220 MHz, it will require a conversion procedure.

Any commercial equipment should be thoroughly checked over before heavy use. Things like bypass capacitors, filter capaictors, etc., have been known to weaken over the years, and blow after a month or two in repeater use. Several repeater groups run their transmitter into a dummy load for 2 or 3 weeks, key down, just to force any early failures.

One final note on the Sensicon "A" receiver. After you get it tuned up and working the best you possibly can, try varying the applied high voltage from 180 to 240 volts. Each individual strip has a tendency to deliver peak performance at a voltage slightly different from any other.

Regardless of the band which you use it, you will find that the Motorola Sensicon "A" is a truly remarkable receiver. Properly shielded and maintained, they are not prone to desensitization or IMD as long as all other system parameters are carefully watched. In fact, one might venture to say that the Sensicon "A" is a truly remarkable, bargain-basement-priced receiver for FM relay service.

MOTOROLA FMTRU 80 AND 140 SERIES TRANSMITTERS

As is, these transmitters are excellent for implementation in Amateur service after conversion and tuneup to 2-meters. They also perform quite well on 220 MHz.

One tip: A lot of metalwork can be avoided if you start with a 60-watt transmitter rather than a 30-watt version. The 60-watter had a type 829B final, and therefore already has a Septar socket in place. This is the same socket required by the new type 5894 final. The 30-/ and 60-watt transmitters are identical except for the final stage.

MOTOROLA SENSICON G RECEIVER CONVERSION

The "G" Strip, as it is called in many FM circles, is a very popular receiver even today. It came in both highband and lowband versions and easily lends itself to implementation in relay systems for Amateur service. Tuneup for use in the Amateur bands is simply a matter of changing the 1st LO crystal and retuning the radio. If the RF and LO multiplier coils refuse to tune properly, adding a 1 to 3 pF capacitor across each coil usually brings them into range. That, and total realignment following Motorola's outlined procedure, yields an excellent receiver.

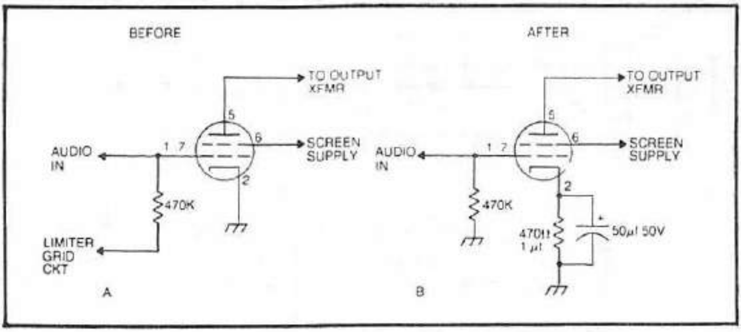


Fig. 14-1. Self-bias conversion of 6AQ5 audio output stage in Motorola Sensicon "G" receivers.

Some of the "G" series receivers ran an "unprotected' 6AQ5 audio output stage, and much tube failure has occured as a result of this. In that receiver version, bias for the 6AQ5's grid was derived from the limiter circuit, and a failure there meant loss of a tube. The situation can easily be cured by converting the audio output stage to self bias as shown in Fig. 14-1. Unground the cathode pin and insert a 470 ohm, 1-watt resistor, paralleled with a 50 μF, 50-volt electrolytic capacitor, from the 6AQ5 cathode to ground. Next, move the 470K-ohm grid resistor from the limiter grid circuit to ground. This conversion will prevent the audio output tube from melting should an I-F tube fail. It can save an audio output transformer for you. Your 6AQ5 will love you for your efforts.

THE CHEAP AND EASY WAY TO GET ON 220 MHz

The following information describes a simple 220-MHz conversion of the popular GE 450-MHz Progress Line equipment. It was originally in *The Decoder*, a publication of the Crestline Amateur Repeater Organization, and was described by Tony Maguire, W6OXZ.

In many parts of the country, for those groups which want to get in on the fun of their own two meter repeater, there are just no more channels available. But, on the 220-MHz band, there are still plenty of channels available. Up till now the problem has been the lack of suitable equipment. Described here is a simple conversion of readily available GE, UHF Progress Line equipment. Results equal or exceed original performance.

The General Electric UHF Prog units are designated MA/E-42 or MT-42 for the mobile version and DO-42 or VO-42 for the base station. A mobile-telephone version was designated the STO-5. All of these units contain the same receiver and transmitter strips, the main difference being the power supply.

The suffix letters in the strip nomenclature denote whether it was wide or narrow band, one or two frequency, etc., and may be disregarded in this conversion.

The Receiver

The receiver is the easiest to convert and the whole process should take no more than an hour.

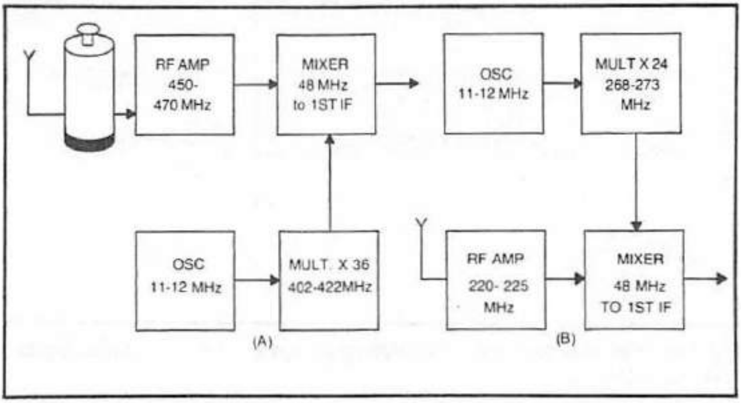


Fig. 14-2. Block diagram of the receiver, unconverted, A, and after conversion B.

Begin first by ensuring that the receiver is working in its unconverted form. No changes will be made in the I-F and audio stages so it's better to determine that these are working beforehand. Any crystal in the 11 to 12-MHz range can be tried in the oscillator socket (pins 2 & 6) to see if it's working. The test points are all of the peak-for-MAX variety, using a VOM. A GDO or a signal generator can be fed into the antenna jack and adjusted until a signal is heard. To find the frequency you are looking for, multiply the crystal frequency X36 and add 48 MHz. It should come out in the range of 450 to 470 MHz. Alternatively, a 48-MHz signal can be applied to pin 1 of V 306. (1st I-F)

Study the block diagram of Fig. 14-2. In the unmodified receiver, the local oscillator signal is injected 48 MHz below the received frequency. After modification, the local oscillator is now injected 48 MHz *above* the frequency that will be received in the 220 MHz band.

Three changes are required to put the receiver on 220. First, remove the UHF cavity as this is of no value on 220 MHz. Second, remove the question-mark shaped coils from around the RF PLATE and MULT-4 PLATE trimmer capacitors, C 302 and C 307 (the coil shields will have to be removed first). Do not disturb the small green RF chokes that are connected near the center of these coils. They will be used with the new coils. Third, wind two three-turn coils, using a PL 259 coax connecter as a coil form, from # 16 bus wire. Install these coils as shown in Fig. 14-3 (In order to insure that the new coils hit the correct frequency range, it is advisable to interchange the RF PLATE and MULT-4 PLATE variable capacitors so that the larger one is now in the RF PLATE position)

Make an RF choke of 10 turns of # 28 enamel wire around a high value ½ watt resistor and connect this from pin 2 of the 1st RF tube to ground (6AM4). Connect the antenna input to pin 2 also.

Select a crystal according to the formula and tune up the receiver in the normal manner. Sensitivity should be in the range of .3 to .7 microvolts for 20dB of quieting. For increased selectivity, a 220 MHz stripline filter may be used ahead of the first RF stage. Details may be found in any recent edition of the ARRL Handbook.

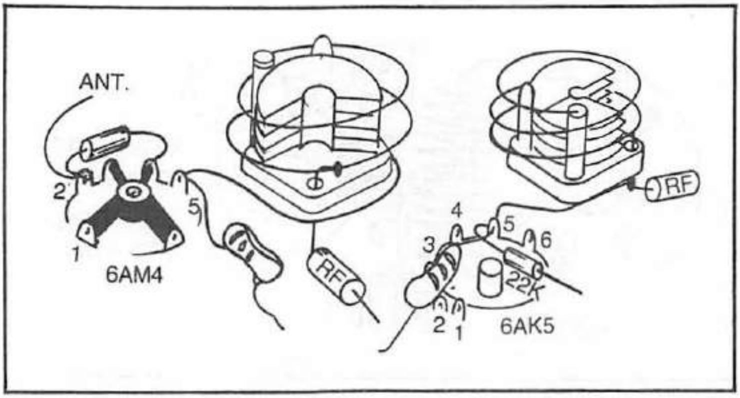


Fig. 14-3. Coil placement for the RF stages. The RF plate coil is on the left, and MULT-4 plate on the right. RF chokes are connected to the center of each coil. When replacing the shield cans, be careful that there are no short circuits.

If a suitable power supply is needed for the receiver, one may be found described in the ARRL FM and Repeaters Handbook, first edition, pages 194 and 195. Power plug connections for the strip described here are the same as for the 4ER25 strip mentioned in the handbook.

The crystal formula is as follows:

$$F\ \text{crystal} = \frac{F\ \text{receive} + 48}{24}$$

Example: Freq 224.86 receive = 11.36913 MHz XTAL

The Transmitter

To begin the transmitter conversion study the block diagram of Fig. 14-4. The original 4ET24XX strips began with a crystal in the 12MHz range

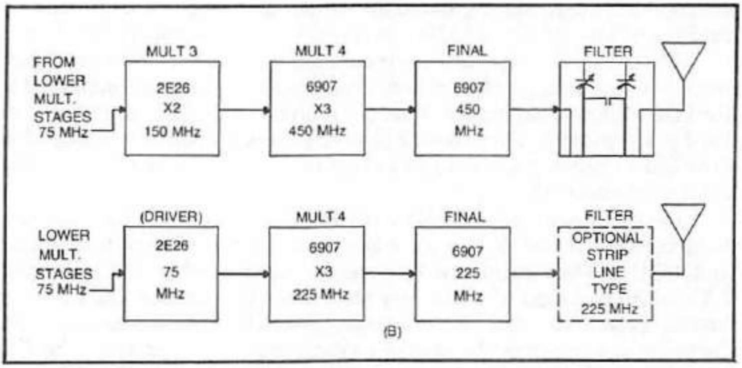


Fig. 14-4. Block diagram of the transmitter before conversion, A, and after conversion, B.

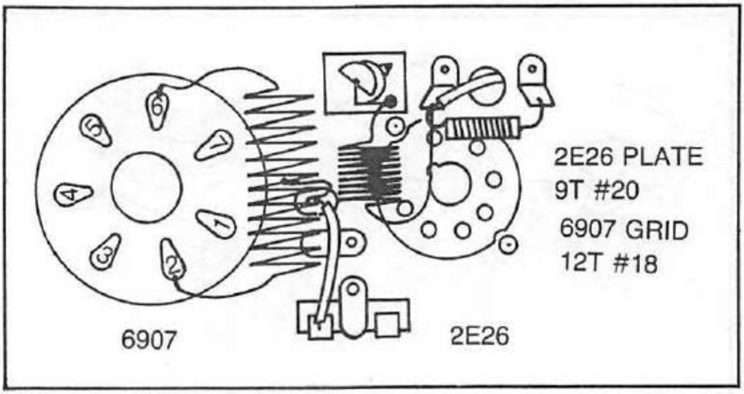


Fig. 14-5. 2E26 plate and Tripler Grid coils. Both coils are ⅝ inch ID., with the plate coil 16 turns per inch, and the grid coil 8 turns per inch.

and multiplied up to a 450MHz output. The modified version starts with a crystal in the same range and uses all of the lower multiplier stages, without changes, until reaching the MULT-3 (2E26) stage. There the 75 MHz signal drives straight through to the first 6907 (MULT-4) triples to 225 MHz, and drives the FINAL 6907 to an output in the 220 MHz band.

The required modifications are mostly coil changes. Two trimmer capacitors are moved to new locations.

The 2E26 Driver. You can start by removing the 150 MHz coil from the plate of this stage and from the grid of the 6907. The grid coil can be saved, and by spreading the turns, used again as the 220 MHz tank circuit for the final. (You will notice that nothing goes to waste in this conversion!)

Figure 14-5 shows the new 2E26 plate coil and the 6907 tripler grid coil. The 2E26 plate circuit now tunes to 75 MHz instead of 150 MHz. The 6907 grid is resonant at 75 MHz but is untuned as it was in the original version. This part of the circuit is not at all critical, and as long as you can get a peak at the MULT-4 test point when tuning you're okay.

6907 Tripler. It was the discovery of a startling fact about the plate circuit of this stage which inspired the author to attempt the conversion of the Prog unit from 450 to 220 MHz in the first place. It is worth telling here.

When the GE engineers were designing the Prog transmitters they were faced with the problem of how tube changes could be accomplished in the field without disassembly of the plate circuit (this had been required in the Pre Prog units). They chose a plate-line assembly which was hinged in the middle to allow it to swing up and out of the way, so the 6907 could be lifted easily from it's socket.

But this posed a new problem. To get the proper clearance for the tube to be removed meant that the plate line was physically too long to resonate at 450 MHz. Their solution will forever be appreciated by 220 MHz band FMers. As any Ham who has ever studied for the General Class license knows, a line (coax, strip line, etc.) which is exactly a half wavelength long, "sees" at one end exactly what is happening at the other end. The GE engineers made the tripler plate line a halfwave length long a 450 MHz, and placed the tuning capacitor at the end opposite the tube. This meant that the line was one quarter wavelength long at 220 MHz. A quarte. wavelength line makes a good resonant circuit. Would it work on 220 MHz? Yes! Merely moving the tuning capacitor back to the tube end, and shorting the line across where the capacitor had been provided the correct resonance for operation on 220 MHz. The rest of the coils were easy to modify and the "220 Prog" was born.

Figure 14-6 outlines the modifications required for the tripler plate and the final grid.

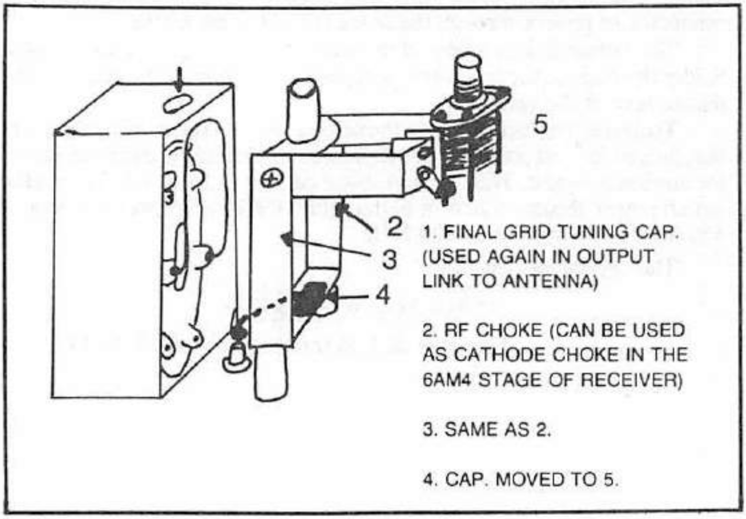
To gain access to the plate line, remove the perforated shield from the transmitter strip on the side opposite the crystal socket. By clipping the leads of the RF chokes, and removing the screws, the plate line can be removed. Unsolder the tuning capacitor from (4) and, by means of solder lugs, mount it at (5).

Drill a hole in the top cover of the transmitter for the capacitor to protrude through, and after final assembly use a lock washer and nut to hold the capacitor in a rigid position.

The final grid coil is a hairpin loop of #14 or #16 bus wire spaced to clear the socket cage by ¼ in. The grid is untuned in this conversion. The associated bias resistors are left in place.

6907 Final. The modifications to the final are shown in Fig. 14-7. The plate-line strip is cut just below the points where the tube pin clips are mounted. To restore the rigidity of the plate coil, an insulated standoff should be mounted on each side as shown. Use solder lugs under the clip nuts, over the plate coil and anchored to the standoffs to hold the assembly rigid.

The 3 turn coil is spaced the width of the original plate line. The bottom of the middle turn should be positioned so it rides up on the B + contactor exactly as the original plate line did.



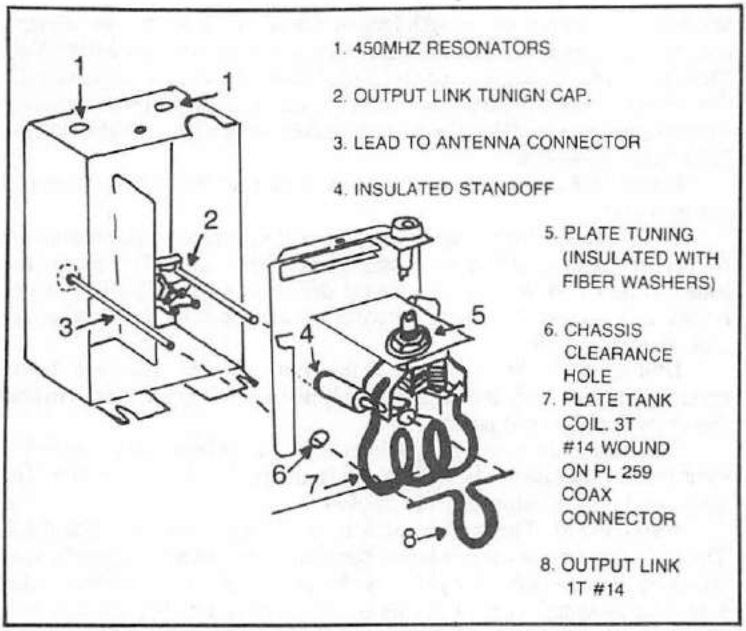
1. FINAL GRID TUNING CAP. (USED AGAIN IN OUTPUT LINK TO ANTENNA)

2. RF CHOKE (CAN BE USED AS CATHODE CHOKE IN THE 6AM4 STAGE OF RECEIVER)

3. SAME AS 2.

4. CAP. MOVED TO 5.

Fig. 14-6. Tripler plate and final grid. The hairpin loop is positioned to clear the cage ¼ inch all around.


1
1
2
3
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8
1. 450MHZ RESONATORS
2. OUTPUT LINK TUNIGN CAP.
3. LEAD TO ANTENNA CONNECTOR
4. INSULATED STANDOFF
5. PLATE TUNING (INSULATED WITH FIBER WASHERS)
6. CHASSIS CLEARANCE HOLE
7. PLATE TANK COIL. 3T #14 WOUND ON PL 259 COAX CONNECTOR
8. OUTPUT LINK 1T #14

Fig. 14-7. Final plate coil and output link. The insulated spacers are used to strengthen the coil assembly.

The 450 MHz resonators are removed from the cage, and the capacitor which was removed from the top of the socket cage is installed as shown. Use a length of stiff bus wire from the capacitor and the antenna connector to project through the holes cut in the back plate.

The output link is soldered in place after the cage is reassembled. Solder the ends to the bus wires, and position the turn of the link near the middle turn of the plate coil.

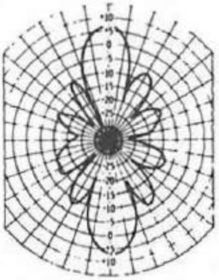
Tuneup. Tuneup is exactly the same as in the original version except that the red RF test point will give no indication. Adjust the output capacitor for maximum output. With 130 mA. plate current (1.3V at CATH t.p.) the output power should be 20W or better. Hint: 6907s which were no good at 450 MHz have worked on 220 MHz

The crystal formula is:

$$\text{crystal freq.} = \frac{\text{output freq}}{18}$$

Example: 223.26 transmit = 12.4033 crystal

Chapter 15
The Ultimate Repeater Receiver



Consider the requirements of a repeater receiver: it must function at peak performance 24 hours a day, 7 days a week, over a wide temperature and humidity range, with the nearest service facility a considerable distance away down a 4-wheel-drive road that isn't there three months out of the year. It must operate at maximum performance, hearing its users at 0.3 μV (−117 dBm) or better, while ignoring a 100 watt transmitter less than 0.2% away in frequency, but in the same rack.

In this chapter, we will describe such a receiver, designed by a professional, specifically for this service—in fact for his own system. It was designed first for performance, second for ease of construction (who wants to work?), third for minimum cost without reducing performance (who wants to spend money?), and fourth to be ignored (who wants to spend hours on a mountain fixing a system?).

This unit is a true departure from the norm in receiver design—a repeater receiver built to NASA-specs, with low noise figure and wide dynamic range as priorities. The overall design exhibits an un-heard-of (in amateur circles) 110 dB dynamic range, superior spurious signal rejection, and a noise figure of less than 2 dB. And, for extras, how about audio response flat within 2 dB from 50 Hz to over 8 kHz, and total audio distortion of less than 1%! As a comparison, the midland 13-509 has a dynamic range of 70 to 80 dB, a noise figure of 4 to 7 dB, and the audio response is horrible. See Table 15-1.

This is not a broad-band receiver. It was designed specifically for repeater service, i.e. single frequency, and hence is not very suitable as a multi-channel monitor receiver. It will probably have noticeable degradation at more than 300 kHz from center frequency, due to the reduced output from the local oscillator module. If a different design were to be used, which maintained the output level and spectral purity, the receiver system would cover a 3 MHz range without degradation.

BEFORE YOU START

This is not a beginner's project, nor one for those not familiar with proper VHF/UHF construction techniques. It is an advanced project and should be undertaken only by those who know what they are doing. All pertinent data is presented in the text, on the diagrams, and in the photographs, for an experienced constructor to duplicate this project.

GAIN-LOSS DATA

ANTENNA +6dB
COAX ½" FOAM—.5dB
DUPLEXER −2.0 dB
RF AMP N.F. −2.0 dB
RF AMP GAIN +11 dB
MIXER −6dB
IF AMP GAIN +116 dB

* ADDED TOTAL NOISE FIGURE 4.5 DB

RECEIVER DATA

DYNAMIC RANGE 110 dB
RECEIVER GAIN 121 dB
20 DB QUIETING −116 dBM
IF BANDWIDTH 12 KC@6dB
60 KC@100dB
NOISE FIGURE 2 dB
IF REJECTION 70dB
IMAGE REJECTION 85 dB (WITH DUPLEXER)
SPURIOUS RESPONSES DOWN
110 dB (20-600 MHZ)
SQUELCH THRESHOLD 119 dBM
AUDIO PWR 1W@3% THD.
AUDIO FREQUENCY BANDWIDTH
40 -9 KC. 3DB POINTS
TB1-3 COR OUT
TB1-4+13.5V REG
TB1-5 GND

Table 15-1. Gain-loss data and receiver data for the WA6VNV repeater.

Use SMA, TNC, or N connectors in this receiver system. *Don't use BNC, RCA, or SO/PL259 connectors*. The BNC and RCA connectors are noisy in RF environments because they depend upon spring action for their only ground connection, and the SO/PL259 is a very poor connector whose impedance varies with frequency. It is about 120 ohms at VHF, which is a lousy match in 50 ohm systems (you don't see them in recent military systems, do you?).

Ray used SMA connectors in his system, along with RG316 coax. The SMA has become the aerospace standard connector.

This receiver system is the present ultimate—but it will not work any better than what you already have if the preceeding equipment is junk. By this, we mean the duplexer, the RF cavity filters, the feedline, the antenna, and all of the interconnecting cables. For example, a set of PL259-type connectors on your duplexer could degrade this receiving system in a high RF environment to the point where it wouldn't work any better than what you have now—in fact, a poor antenna system would be penalizing your current system! Two more points: a junky antenna system will degrade your transmitting performance as well as your receiving performance, and a antenna system is no bargain.

Take some clues from the people who build and maintain two-way radio equipment for a living—don't use anything but 'N' connectors on a mountain. Use *good* coax—stuff like RG 213, 214, 223, etc. The old standard, RG-8, no longer has a mil-spec, and these days the manufacuterers can sell anything as RG-8. Most of the foam-type is only 85% shielded, and the best RG-8 was only 91%. All the cavities in the world won't help if the RF at the site is coming in through the shield of the coax jumper between your cavity or duplexer and your receiver. If you need it, consider the shielding that 214 and 223 give—they are double-shielded, with shield densities around 99.1%. Keep in mind that parallel coax cables with inadequate shields can couple RF into each other (just like a transformer), and

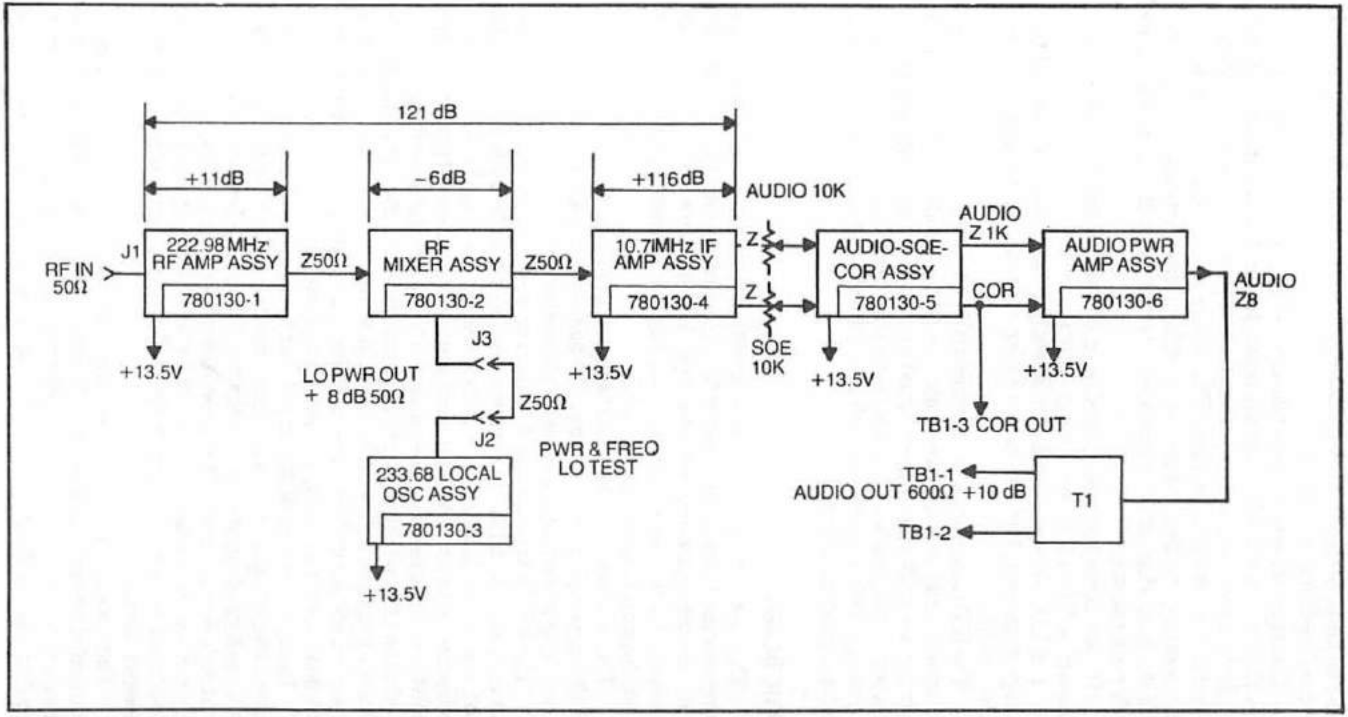


Fig. 15-1. WA6VNV repeater receiver block diagram.

make a mess of receiver performance. This happens most often with antenna feedlines on towers.

This receiver system uses Siliconix U-310 JFETS in the RF, I-F, and LO modules. Do not substitute any other device. Use the metal-case, not the plastic-case devices. The performance of this system will suffer drastically if any other device is used. This device was carefully chosen for it's ultra-linearity, dynamic range, and stability characteristics. These, along with the grounded-gate configuration, are the major factors in this receiver's performance.

Do not scrimp on the bypassing or decoupling that is shown on the schematics. All of it is there for good reason.

The LO, I-F amp, and Audio-Squelch-COR modules are individually voltage-regulated. This was done to keep the coupling through the power supply down.

The JFD capacitors in the front end (C1, C2, and C3 in the RF module) are stable, wide-temperature-range, piston-type units. They are expensive, but were chosen for a very good reason: when the first cold spell, or heat wave, hits your site, you don't want your front end to detune and loose sensitivity. Other parts were chosen for other equally good, although perhaps obscure reasons.

BASIC DESIGN

The basic receiver design is single conversion. This may surprise some readers familiar with double or triple conversion receivers, but the more conversions there are, the more images there are, and with this receiver, double conversion does not buy any additional performance. A block diagram is shown in Fig. 15-1.

The receiver is modularized, with the front end, the mixer, the local oscillator-multiplier, the I-F amp, the audio-squelch-COR, and the audio power amp having their own separate modules.

The RF, Mixer, LO, and I-F modules are all 50 ohm in and out. This makes it easy to build, as common test gear can be used to debug the modules as you build them. For example, as soon as the I-F module is completed, a common 50-ohm signal generator can be used to test it. When the Mixer is finished, it can be connected to the I-F, the same RF generator used as an LO, and with a 50-ohm antenna hooked to the input, strong local stations should be audible. The LO module can be tested with a sensitive power meter (be careful—power meters aren't frequency sensitive, and you don't want to tune up on the wrong harmonic).

In any equipment designed and built for unmanned, automatic, "turn-on-and-forget" operation, in an environment such as a mountaintop or other site, mechanical rigidity and RF shielding is even more important than at the amateur's home station. The home station usually has at least a heater to maintain the temperature above 68° F (20° C), and many times an air conditioner to keep it below 90°F (48° C)—luxaries not found at most repeater sites!

The receiver system shown here was built in surplus, machined-aluminum housings manufactured for spacecraft tracking equipment. The design of these housings stresses RF shielding and mechanical rigidity first, and didn't worry about the cost, or ease of the manufacture or assembly of

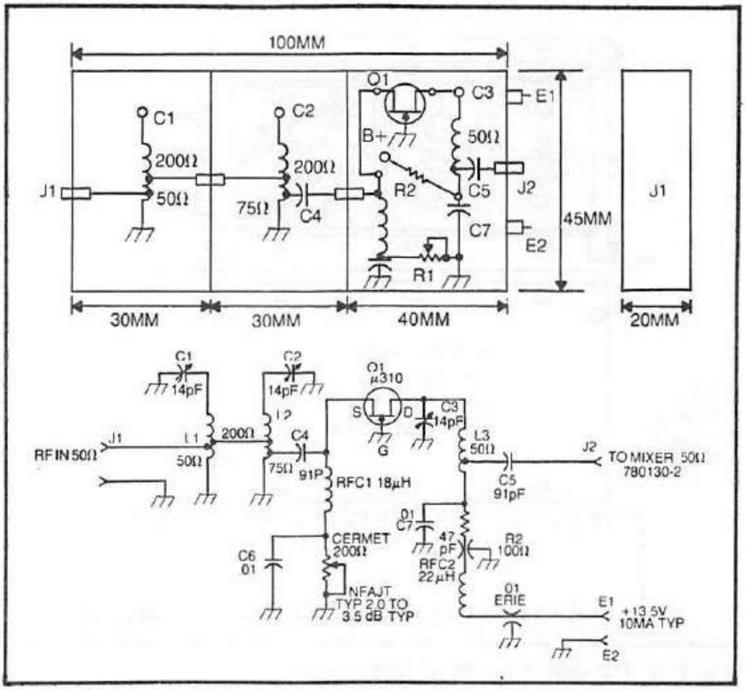


Fig. 15-2. RF amplifier assembly schematic diagram.

the housing itself. This is nice, but isn't practical in the amateur radio world. On the other hand, we have to come up with an equivalent—if an RF amp were built on a PC board of copper on paper, as soon as it was moved, the circuit would be detuned, not to mention the microphonic aspects. Views of the RF assembly are shown in Figs. 15-2 through 15-4. Table 15-2 includes coil data.

The module housings used were estimated to cost over $700 a set, but there is a way to get equal performance—both mechanical and shielding—by building them out of *double-sided epoxy* board. Simply take the dimen-

Table 15-2. Coil data and notes for the RF-amplifier assembly.

L1, L2, L3: 3.5 TURNS OF 1MM DIA TINNED WIRE 8MM DIA. SPACED 2 MM.
L1, L3: 50Ω TAP, 1½ TURN FROM GND.
L2, L2: 200Ω TAP, ½ TURN FROM GND.
L2: 75 Ω TAP, ¾ TURN FROM GND.
L3: 50Ω TAP, ½ TURN FROM GND.

C1, C2, C3 JFD VC20.
GAIN = 11 dB.
NOISE FIGURE = 2.0 dB.
DYNAMIC RANGE = 116dB.
BANDWIDTH 3 dB ±1 MHZ,
10 dB ± 4 MHZ.
3RD INTERCEPT POINT + 25dB.
1 DB COMPRESSION +5 dB.
OVERLOAD POINT AT INPUT +15 dB.
MAIN CHASSIS FRAME 1.5MM THK.
DOUBLE SIDED TINNED COPPER EPOXY.
Q1 SILICONIX U310
1 RF CONNECTORS SMA 3MM FLANGE.

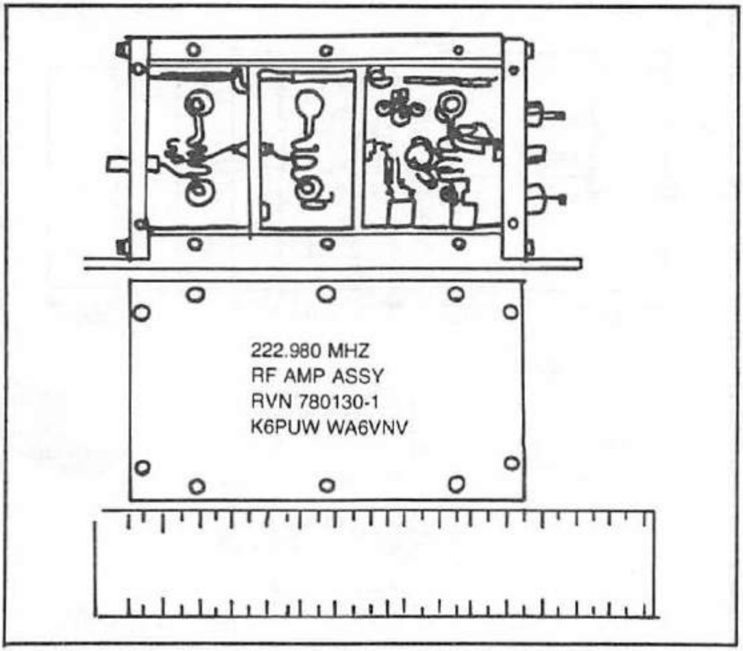


Fig. 15-3. Top view of the RF amplifier assembly.

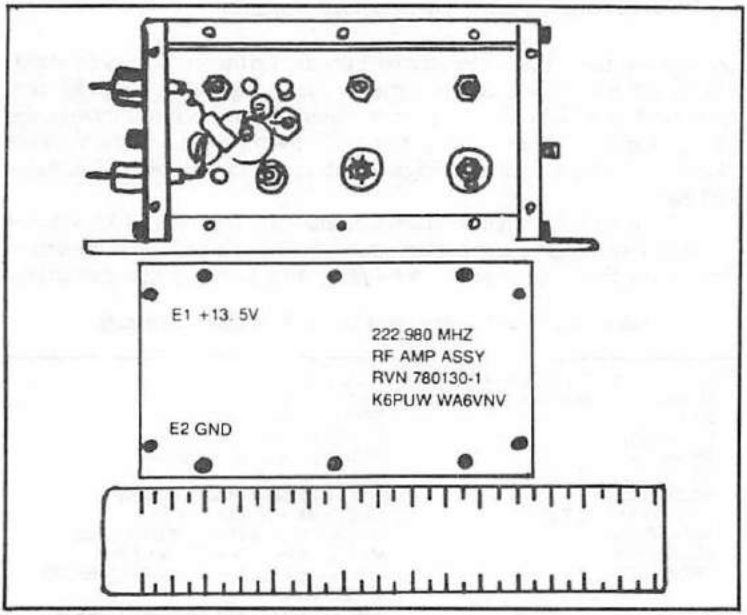


Fig. 15-4. Bottom view of the RF amplifier assembly.

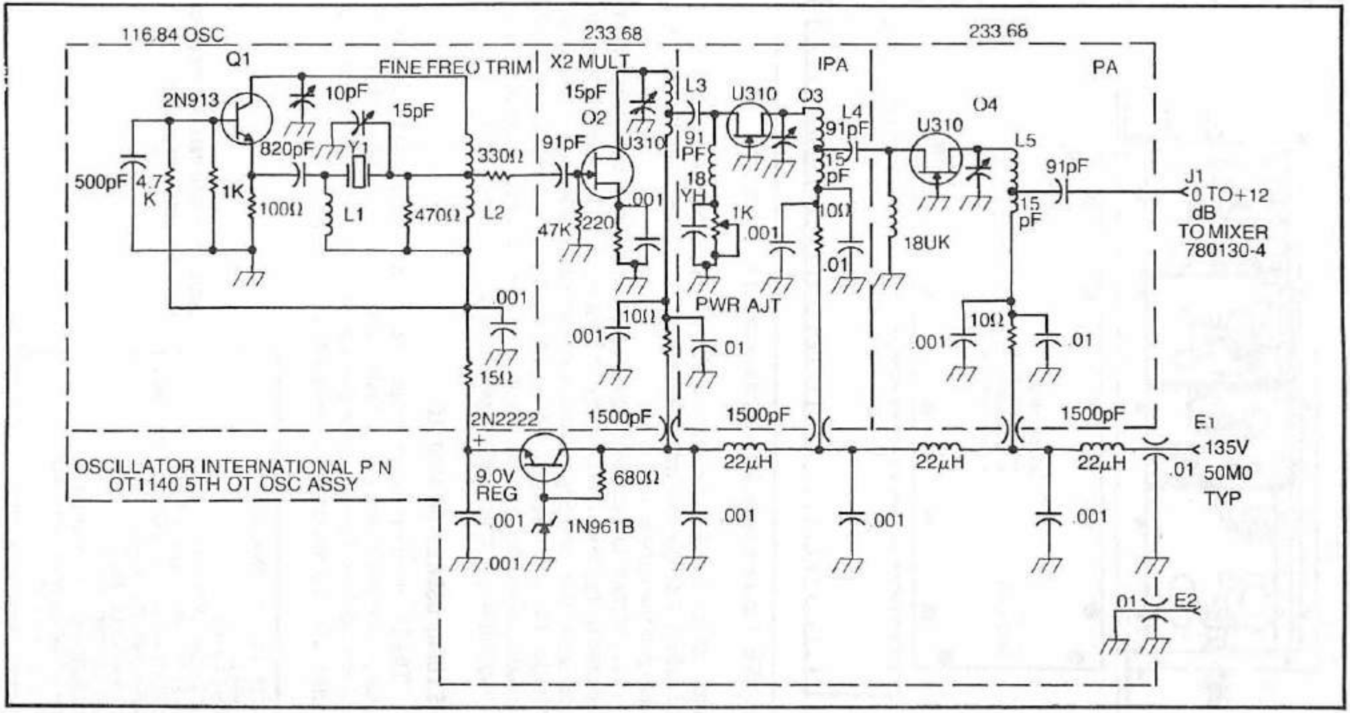


Fig. 15-5. Schematic diagram of the 223.68 MHz local oscillator.

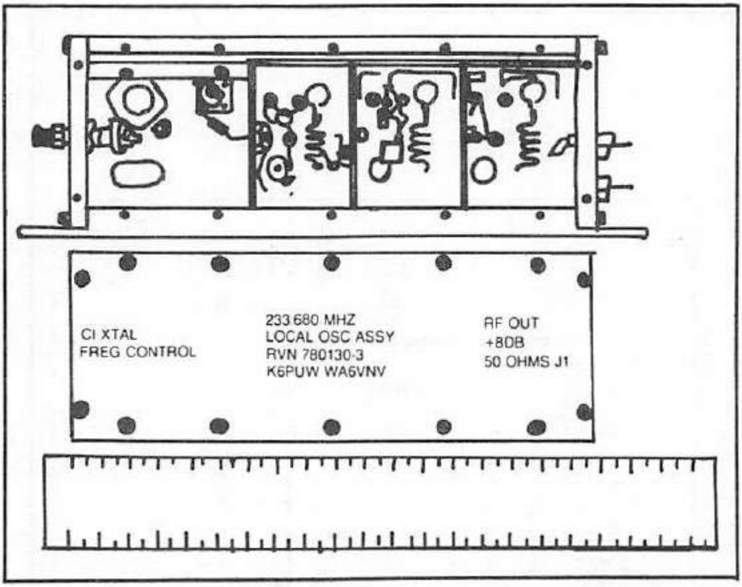


Fig. 15-6. Top view of the local oscillator circuit and enclosure.

sions, cut the board, and solder together all the corners and edges, *inside and outside*—double shielding at low cost. Don't forget to ground both the inside and the outside foil.

An alternate housing technique is the use of "Pomona Boxes", manufactured by the Pomona Company, in Pomona, CA. They make excellent housings for this receiving system, have excellent shielding properties, and are rigid. The only disadvantage is the technique used to make them rigid: the housings are die-cast, and the material used can't be soldered to. The only grounding technique that works is solder lugs and screws.

THE LOCAL OSCILLATOR MODULE

The LO module is unusual: it puts out 10 mW—and would make a nice signal source on it's own, except that series-resonant crystal oscillators are hard to modulate. The reason for the high level is that one characteristic of double-balanced-mixers is that they need high drive.

L3, L4, L5: 1MM TINNED.
8 MM DIA.
SPACED 3MM.
QZ-Z4 SILCONIX U310
Y1 SPEC WIDE TEMP @ 5TH
OVERTONE CUT. P/O OT-1140 MATCHED
SUB-ASSY. MEASURED 0°C
TO +40°C. LO 380 C/S, HI
190 C/S. TYP .0005%
FM NOISE NOT MEASURABLE.
AM NOISE DOWN 75 dB @ 300 HZ.
Po 0 TO + 12 dB.

Table 15-3. Coil data and notes for the local oscillator module.

The coil-winding forms used here and in the RF module are readily available at any auto parts store—they are standard 8 and 10 mm bolts, commonly called "M8" and "M10" bolts. Simply wind the wire in the threads, then unscrew the bolt from the wire. Various views of local oscillator are shown in Figs. 15-5 through 15-7. Table 15-3 includes coil data.

The LO chain uses high-side injection to keep the image away from the high VHF TV channels—11, 12, and 13 which range from 198 to 216 MHz.

You will note that this LO chain starts out high in frequency; at 116.84 MHz, doubling to 223.86, for high-side injection for a 222.98 receive frequency. There are a number of reasons for this, but they all boil down to "why start low, and multiply up, in extra stages, having to filter as you go, when by starting high, and multiplying once, you have a simpler system, and a cleaner spectrum?" Remember: Every multiplier adds trash.

The LO module uses a International Crystal oscillator module which is purchased with your crystal custom ground, installed, stabilized, adjusted, and sealed. This results in a stable and spectrally pure signal at a price that the average Amateur can't duplicate (at the time of this writing), for less than $40. The stability and spectrum is better because the oscillator module circuit is totally matched to the crystal (one manufacturer does it all). There is a trimmer to net the crystal, if necessary. This is much better than if the builder simply bought a crystal for his own circuit. Simply stated, let the crystal maker do all the work. There is a good article that covers LO circuits in *ham radio* magazine for July, 1979, by N6TX, where he writes about his 380-540 MHz LO chain.

A 116.84 MHz oscillator and a doubler was used to get to 223.68 MHz, instead of 74.56 MHz and a tripler because "triplers are trouble!" Gener-

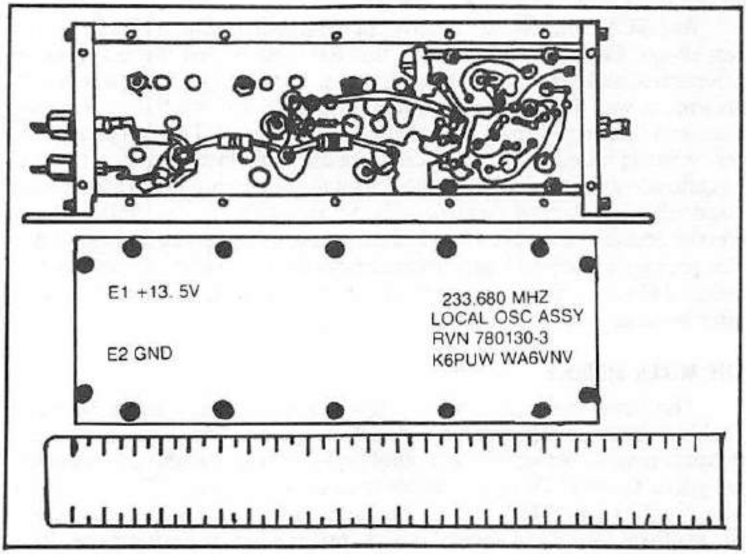


Fig. 15-7. Bottom view of the local oscillator.

ally a tripler output has all the odd multiples, i.e., X3, X5, X7, X9, etc., *and* all of the odd and even multiples of those odd multiples! On the other hand, a doubler has X2, X4, X8, but no odd, or odd X even, or odd X odd multiples. A 58 M/MHz oscillator and two doublers could have been used, but why design, build, stabilize, and debug an extra doubler stage when the 58-MHz and 116-MHz oscillator modules are the same price?

The circuitry of the doubler is very straightforward up to the two gain stages. These are run as grounded-gate, class A and use the U-310 JFETS. The same reasons hold here as earlier—the most important ones are stability, and spectral purity. You might wonder about the tuned circuits—each and every one contributes to the clean spectrum, and none are broadbanded as in a typical multi-channel Amateur mobile rig.

The name of this game is the production of a clean and stable signal to use as injection to a mixer. For every bit of trash at this point, you will hear a proportionate amount of trash in your receiver output.

THE RF MODULE

The RF module uses a low-gain (11 dB), low-noise, stage to drive the mixer module, because this improves the spurious response and overload performance. The high gain portion of this receiver is in the 10.7 MHz I-F module, which contains 8 or 12 poles of crystal filter and 2 high-gain amplifier stages.

The physical size of this module is important—you will notice that there are physical measurements specified on the schematic—"tuned cells" are used as input circuits, with critical interstage coupling. This maintains interstage isolation, and improves out-of-band rejection. If possible, tin- or silver-plate the front-end components to reduce noise figure. Remember the "skin effect's—at these frequencies, all of the signal energy is traveling on the surface of the wiring, so silver plate helps, but is not required.

An N6CA "Anglelinear" receiver preamp (sold by Lunar Electronics in San Diego, Ca.) is very similar to this RF module, but there are some differences, and hence some disadvantages. For example, being a receiver preamp, it was designed to be 5 MHz wide. To achieve this, it has less front-end filtering—it has 1 pole where Ray's has 2. The completed receiver would be less selective if this were used, but in many cases it would be quite adequate. It does have the advantage of arriving already built, so if you don't need super performance (i.e. a non-saturated site), and you don't feel comfortable around low-level RF circuitry, this might be the way to go. The preamp has almost identical circuitry as the RF module, except for the reduced filtering. You will have to specify the connectors desired, as they offer several.

THE MIXER MODULE

The mixer module is very simple—3 connectors, and a 50-ohm, double-balanced-mixer module. The DBM was used because of it's large dynamic range—better than any other type of mixer available at a reasonable price. These DBMs are available from several sources: The ones from Mini/Circuits Labs, 14th Street, Brooklyn, NY; from Anzac Corp. Green St. Waltham, MA.; and several others, provide similar performance. The mixer is in it's own box for shielding. If you are going to duplicate this

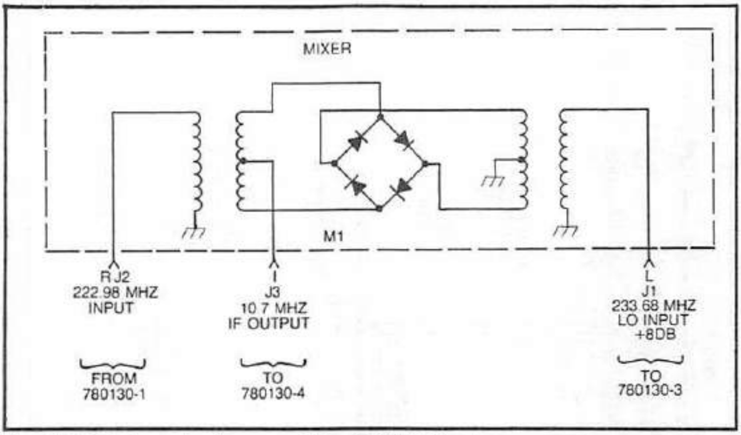


Fig. 15-8. Schematic diagram of the WA6VNV mixer.

receiver, it is suggested that you get a Mini-Circuits model ZFM-3, which comes in it's own shielded housing, with your choice of SMA, TNC, N, or BNC (not recommended) connectors. This will save you from having to manufacture another housing for the PC-board-type of mixer that Ray used. The mixer module has a net signal loss of approximatley 6 dB, so at this point we're 5 dB ahead (the RF module gave us 11 dB). Refer to Figs. 15-8 and 15-9.

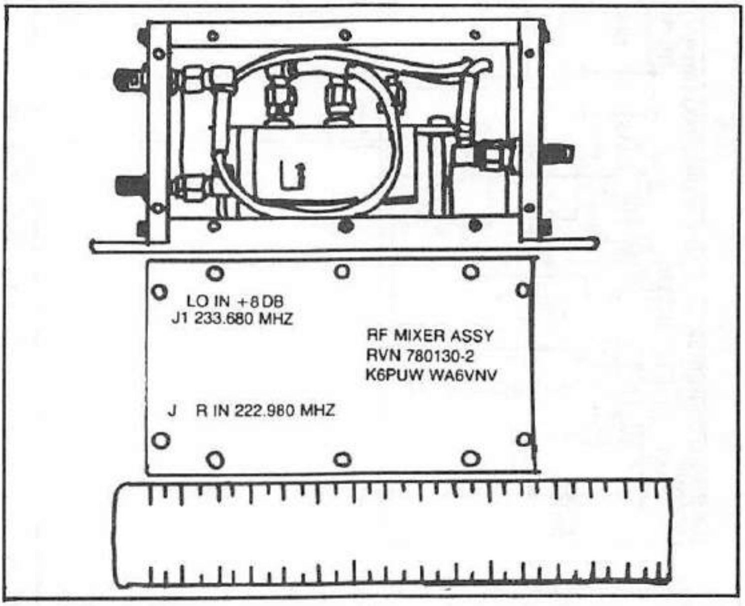


Fig. 15-9.The mixer assembly is placed in a metal enclosure with SMA connectors.

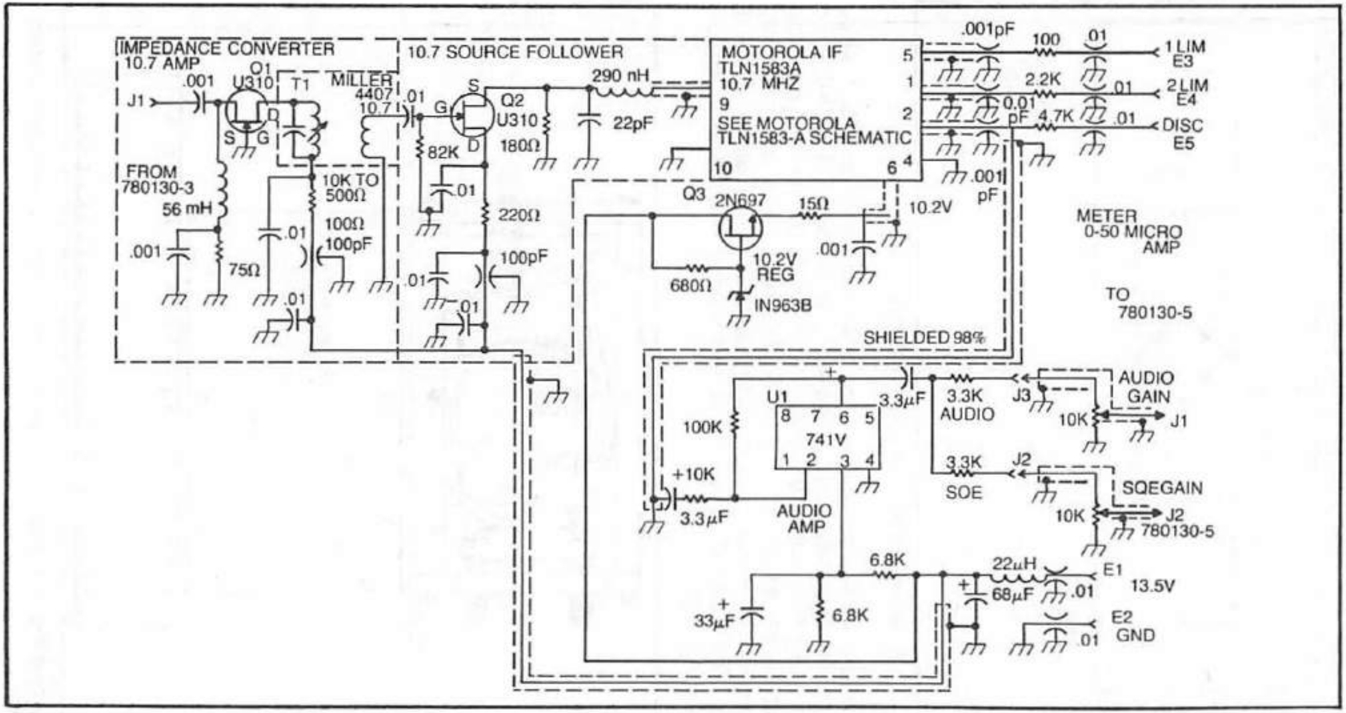


Fig. 15-10. Schematic diagram of the 10.7 MHz I-F amplifier.

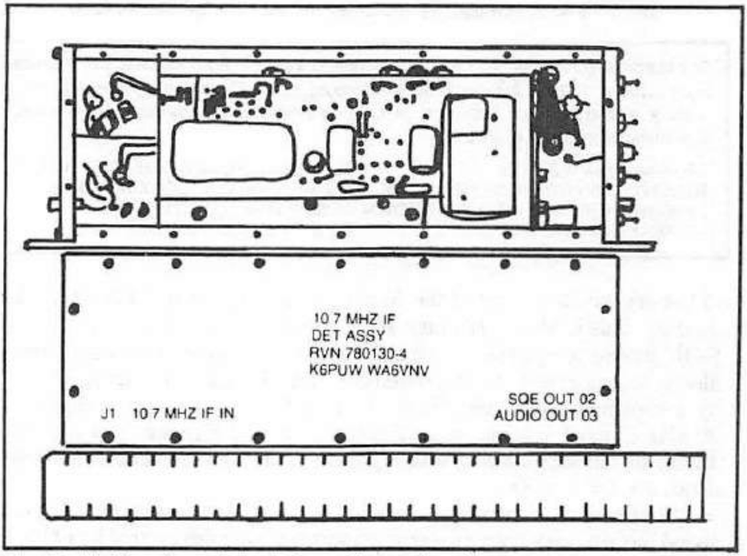


Fig. 15-11. Top view of the I-F amplifier and enclosure.

THE I-F AMPLIFIER MODULE

The I-F module shown in Figs. 15-10 through 15-12 uses a U-310 (for low noise figure) as a grounded-gate amplifier, driving a standard 10.7-MHz I-F transformer (one out of a transistorized FM broadcast radio is ok). The next stage is a source follower, which is necessary to match the impedance

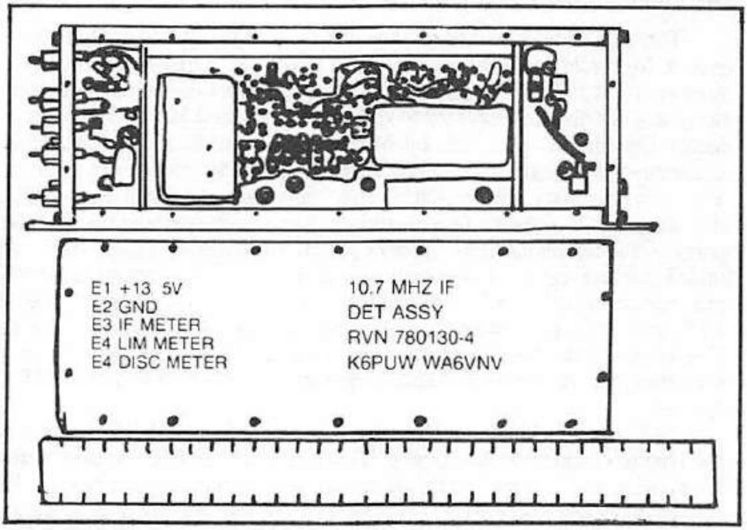


Fig. 15-12. Bottom view of the I-F amplifier.

Table 15-4. Specifications and notes for the I-F amplifier module.

The Motorola TLN1583A, 10.7 MHz I-F module is available from Motorola Communications Division, 1301 E. Algonquin Rd, Schamburg, IL 60172. The manual publication number is 68-81020E42. These can be ordered either direct, or through any Motorola Communications parts distributor.

I-F noise figure = 3.0 DB
REMOVE C38 (.01) FROM 1583-A DISC.
I-F BANDWIDTH ±30 KC, 100 dB DOWN.
I-F ASSY GAIN 116 dB

ALL AUDIO, POWER SHIELDED RG174/U
,ALL RF SHIELDED COAX RG 188/U
J1 SMA 3MM (OSM 215)
O1 & O2 SILICONIX U310.

of the crystal-filter input of the Motorola TLN 4245A or TLN 4245B I-F module. This is Motorola's only 10.7-MHz module—it is from the "PULSAR" mobile telephone. It contains four or six 2-pole, monolithic crystal filters, interspersed between two high-gain I-F amplifier stages, followed by a sensitive crystal discriminator. The TLN 4245A was designed for 30-kHz channel spacing with 12 poles of crystal filtering, and the TLN 4245B for 15-kHz spacing with 8 poles. Table 15-4 contains other notes about the I-F amplifier.

You'll wince at the price—about $200—It's worth every penny! You'd spend more money trying to come up with a similar device that had 116-dB of gain, with the same great selectivity, and noise figure involved, and then you would find that the crystal-filter impedances didn't match those of the amplifiers. What is a couple months of your R&D time worth?

Note that you'll have to remove C38 from the I-F module—because in the mobile telephone service for which it was designed, no squelch circuit is needed, and this capacitor rolls off all of the high frequencies above about 5 kHz. With no high frequencies, you'll have no squelch action.

THE AUDIO-SQUELCH-COR MODULE

The audio-squelch-COR module shown in Figs. 15-13 through 15-15 uses a Motorola M6907 chip from the "MICOR" radio (Motorola part number 51-84267A09, available from any Motorola Communications division parts distributor. Don't try to get it from your local Motorola Semiconductor Distributor—it's built by Motorola Semiconductor for Motorola Communications, and a Motorola Semiconductor distributor can't get it). The main reason for the use of the Micor "smart-squelch" chip was to make the autopatch a pleasure to use, rather than an ear-crashing pain for the party on the telephone. The "smart squelch" produces no squelch tail at all on full quieting signals, and a progressively longer tail (maximum about 600 mS, minimum is a "click") as the quieting goes down. Also, it takes a signal 15 % quieter (approximately) to open the squelch than it takes to close it. The length of the tail can be used as an audible "S-Meter." The internal structure and theory of the chip's operation is covered in any MICOR manual.

In Motorola's Micor squelch circuit, they use the dual FET switches in the chip to clamp an audio op-amp. This causes an audible transient when the squelch closes, which on the air sounds like a "click". This circuit, on the other hand,uses these FET switches in a passive AC-coupled audio attenuator that is totally silent and click-free. Many times all you hear is the

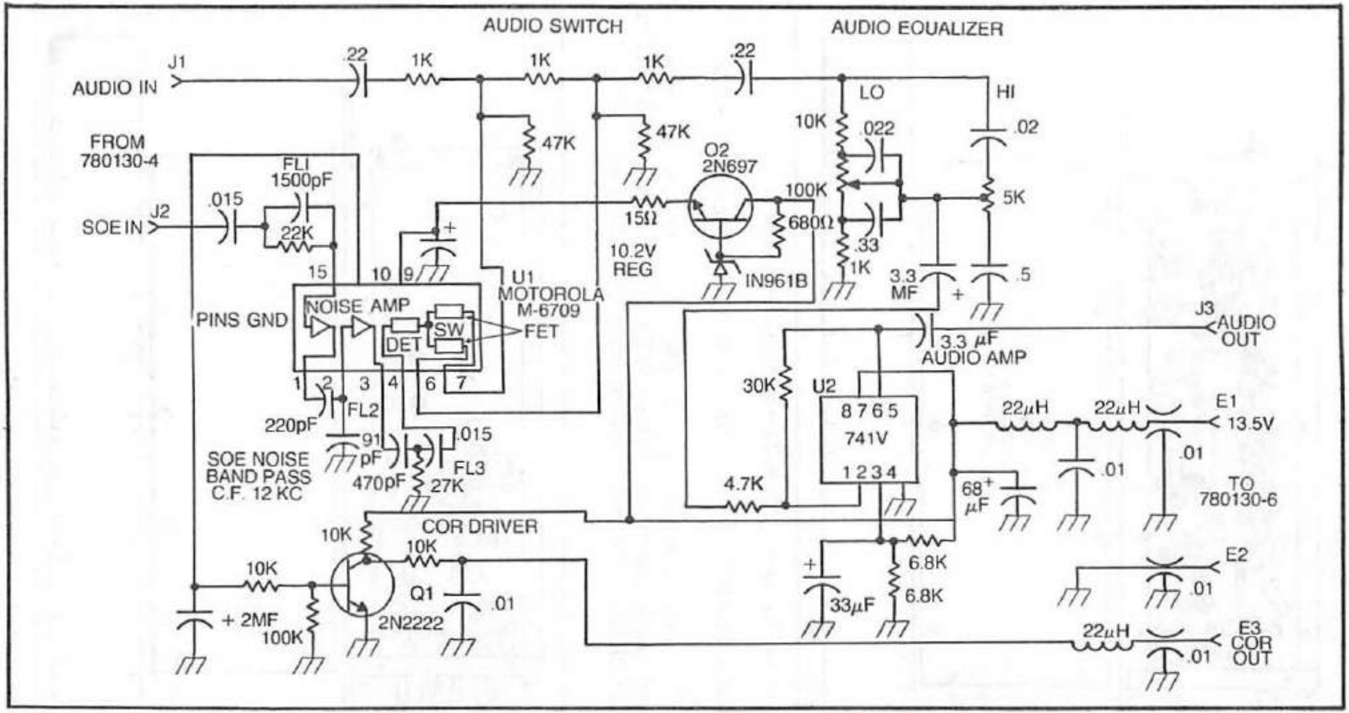


Fig. 15-13. Schematic diagram for the audio-squelch-COR board.

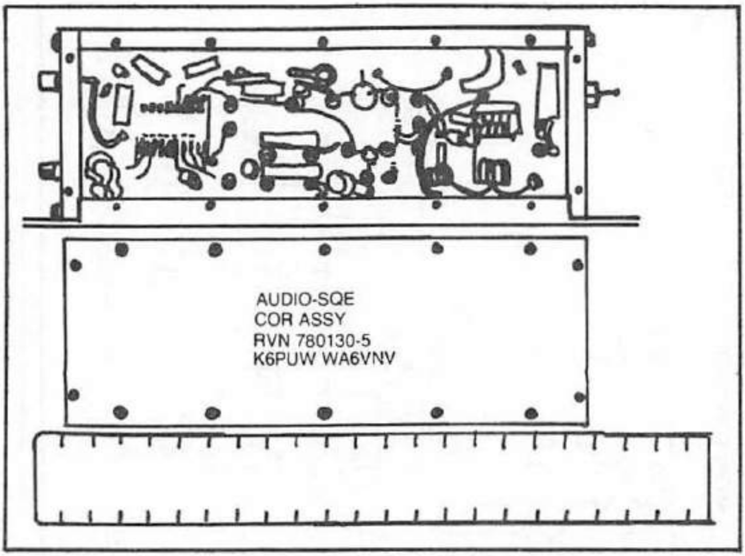


Fig. 15-14. Top view of the audio-squelch-COR module.

mechanical noise produced by the mic button moving in the microphone case.

The audio band-pass filter that feeds the noise-amp section of the squelch chip is centered at 12 kHz—Motorola's is centered at 8 kHz. This change eliminates several problems: When any clipping is present in the

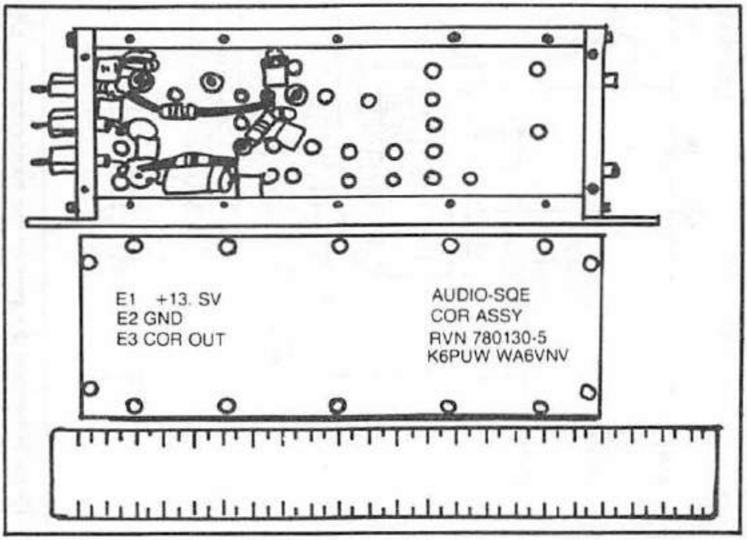


Fig. 15-15. Bottom view of the audio-squelch-COR.

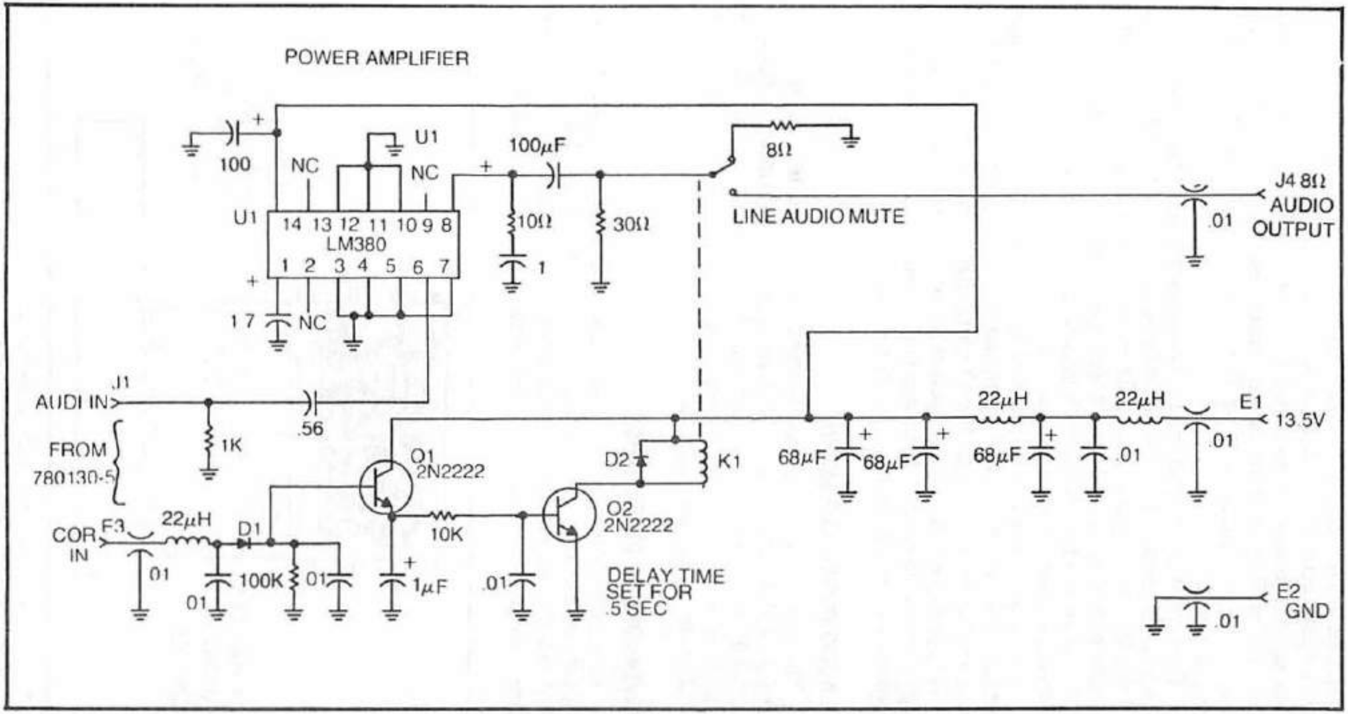


Fig. 15-16. Schematic diagram of the audio power amplifier using an LM-380.

microphone audio section of a user's radio, the resulting noise sidebands causes many receivers to "squelch-out" momentarily—but not this one. Those same receivers will also squelch-out (or try to) on alternator-whine harmonics, off-frequency hetrodyne squeals, etc. Ever notice that some receivers tend to squelch-out on Touchtone-modulated weak carriers? This one won't.

The further away from the I-F bandpass this noise amp center frequency is, the greater the reduction of these problems—but—if you go too far, you lose the squelch action. There is a distinct tradeoff here; for optimum performance, you want a high noise-amplifier center frequency, but if you go too far, the squelch gets sloppy. The shape factor of the I-F-amplifier filter controls how far you can go.

This squelch circuitry is followed by a Hi-Fi base and treble stage disguised under the name of "audio equalizer." This equalizer is adjusted to obtain a flat system—one that doesn't sound tinny or bassy. The last stage is a 741 preamp with a 1000-ohm output impedance. At this point you have response from 50 Hz to 8 KHz, and here is where you would attach any decoders—CTS, tone-burst, Touchtone, etc.

THE AUDIO POWER AMP MODULE

The audio power amp module shown in Figs. 15-16 through 15-18 contains a LM380 power IC, with 8-ohm output for a local monitor speaker. The "COR-in" function on the schematic is an audio-mute feature that can be used at your option. A 600-ohm transformer is shown, to drive a 600-ohm line, but is also optional.

CONVERSIONS TO OTHER BANDS

As mentioned before, this design, shown finished in Fig. 15-19, was originally for 220 mHz, and the only receiver of this design that exists is in the WA6VNV repeater. K6PUW sat down one evening in July, 1979, and figured out the conversions for other bands, just for this book. Here we

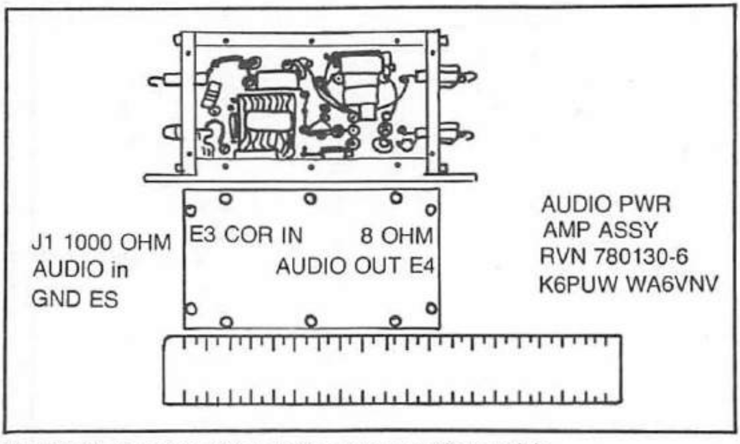


Fig. 15-17. Top view of the audio power amplifier module.

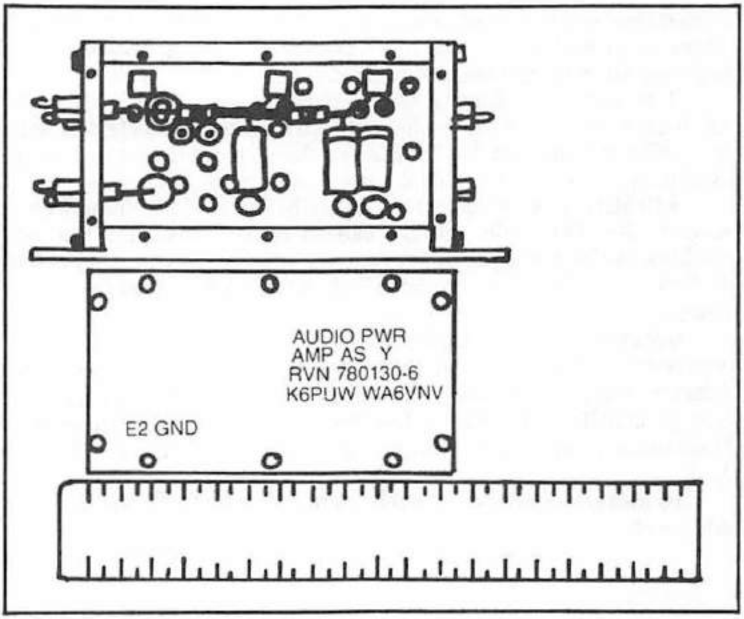


Fig. 15-18. Bottom view of the audio power amplifier module.

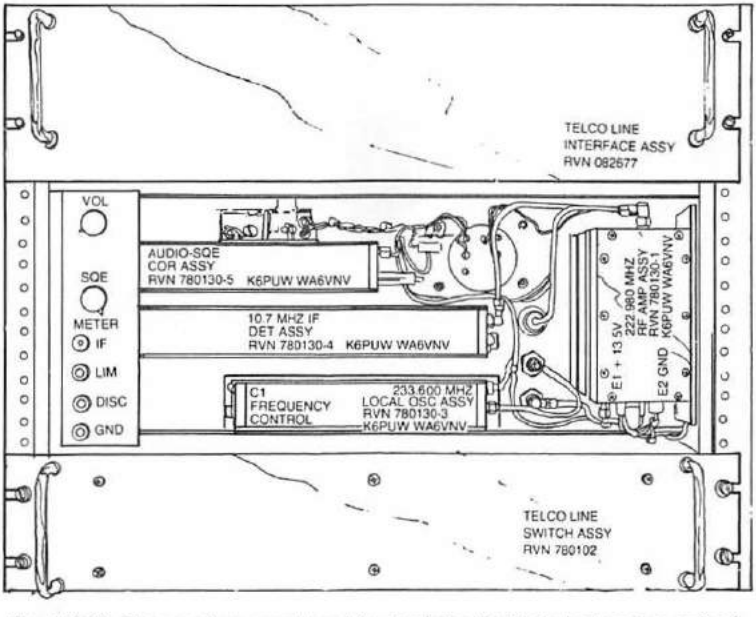


Fig. 15-19. The receiver panel and its modules fit nicely between a pair of telephone-line interface and switch panels at the WA6VNV repeater.

present theoretical information; it should work, but hasn't been tried. There is no reason why this receiver couldn't be put anywhere once someone sat down and decided to do it.

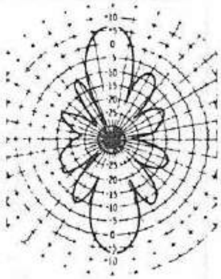
2 meters: Add 2 turns to the capacitor end of the coils in the RF-amplifier module. Remove the doubler from the LO module, and order the oscillator module for 10.7 mHz *above* the received frequency (they're available up to 170 MHz). Add 2 turns to the LO amplifier coils.

440 MHz: Reduce number of turns in the RF coils by identical doubler stage to the LO module, with the number of coil turns cut in half. The oscillator module should be ordered for low-side injection, i.e., (440 MHz-10.7)/4. The noise figure may be as high as 3 dB due to skin-effect circuit losses.

6 Meters: This gets trickier due to the size of the inductors. The RF amp and the LO would also require larger boxes. One possible source of inductors might be 45 MHz. TV I-F coils, with the capacitors replaced to tune to 52 MHz. J.W. Miller in Los Angeles is one source of these coils. Don't use any doublers in the LO. Use high-side injection, i.e., 52.525 + 10.7.

10 Meters: Similar to 6 meters, with coils out of a CB set. Use low side injection, i.e., 29.6 - 10.7.

Chapter 16
Improving Receiver Performance



In many cases, both overall system sensitivity and dynamic range of your receiver's front end can be improved by the addition of a good, low-noise RF preamplifier. For example, after converting a General Electric Progress Line receiver to 220 MHz, it will probably exhibit a sensitivity of about 0.8 to 1.0 microvolts. However, simply by placing a good preamp—such as the AngleLinear—ahead of the receiver, it can be made to "play" at a typical 0.2 microvolt or better sensitivity level. AngleLinear preamps for various bands are available through Lunar Electronics in San Diego, California. For those of you who wish to "brew your own," we present the following designs. First is a 220-MHz design from Ron Whitsel, WA3AXV, see Fig. 16-1. This preamp was originally published in "Cheese Bits," the publication of the Mt. Airy VHF Club, and "QRZ," the publication of the Rocky Mountain Radio League, and was provided by Jim Labo, K0OST.

THE WA3AXV 220 PREAMP

The preamplifier shown in Fig. 16-1 was developed for use in a mobile installation, but should work just as well ahead of any 220-MHz receiver. Parts are not critical, and any reasonable layout should produce excellent results. Gain will be 10 to 12 dB, which will take the average transceiver down to $0.1\mu V$ for 20 dB of quieting.

Coil information is:

L1— 2½ turns, ¼-in. dia., No. 16 tinned wire. Tap one turn from cold end
L2— 3½ turns, ¼-in. dia., No. 16 tinned wire.
L3— 1 turn insulated hookup wire, inside cold end of L2.

Q1 is a 40673 dual-gate MOSFET, C1 and C5 are miniature ceramic or piston trimmers. C3 is a ceramic feed-through capacitor. Input and output connectors can be whatever matches the rest of your equipment. All resistors can be ½ or ¼ watt carbon types.

A 6CW4 NUVISTOR PREAMP

The following preamp was designed in 1970 for a tube-type repeater which used an RCA Carfone receiver. It is designed for noise-figure reduction, rather than increased sensitivity, and therefore exhibits unity gain. The circuit has a type 6DS4 nuvistor triode in grounded-grid configuration, providing a noise figure of under 3 dB (Table 6-1).

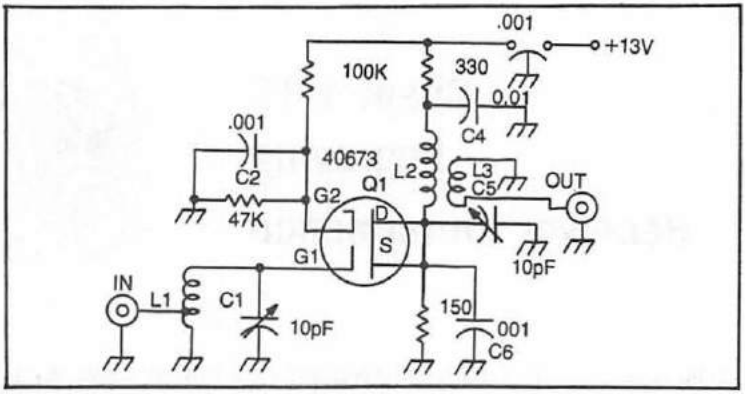


Fig. 16-1. The WA3AXV 220-MHz preamplifier.

The preamp was built in a 2 x 3 x 1-inch project box (aluminum), with easily procured components. Tuneup is simple and, once aligned, it rarely requires readjustment. Since the tube grid is operated at a low AC (signal) impedance, and at DC ground, no special shielding is required. The circuit appears in Fig. 16-2. Alignment requires only peaking L2 with the piston trimmer for maximum output. Table 16-1 shows coil-winding information.

A CAVITY FRONT-END FOR 220 MHz

The following is reprinted with permission from *QRZ*, a publication of the Rocky Mountain Radio League, and was supplied by Jim Labo, K0OST (originally by W0PWG).

"After I converted the GE receiver for 220 MHz, described in the July issue of *QRZ*, for use in a repeater, I added a Hamtronics (Rochester, NY) P-9 preamp and a homebrew coaxial cavity. The preamp is specified to have 20-dB gain, and it does. It costs $9.95, and comes with instructions to build it for any frequency from 26 to 230 MHz. The power requirement is twelve volts DC (actually it'll work with anywhere from 10 to 15 volts) at 10 to 20 milliamperes. I "borrowed" some voltage from the receiver power supply,

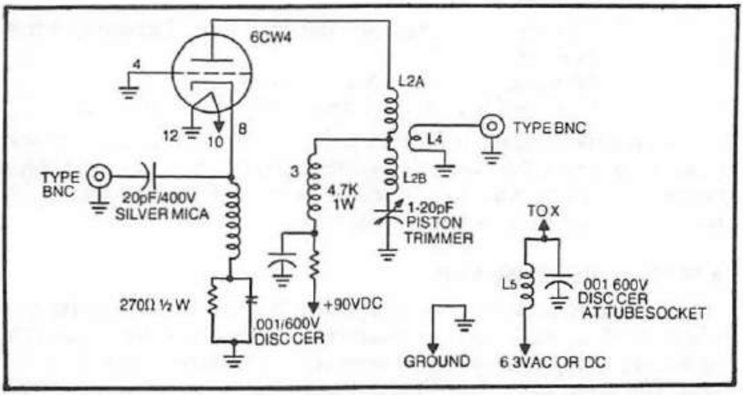


Fig. 16-2. The WA6ITF Nuvistor 2-meter preamplifier.

Table 16-1. Coil information for the Nuvistor preamplifier.

L1 & L3—Ohmite type Z-144 RF Chokes

L2A & B—10 turns total, No. 20 tinned wire, spaced 2-wire dia., ⅜-inch I.D. Approximately ¼-inch separation between turns 5 and 6.

L4—2 turns solid hook-up wire inserted in center of L2.

L5—6 turns insulated hook-up wire, closewound, ⅛-inch I.D.

through a feed-through capacitor, and the sensitivity of the receiver improved to better than 0.1 microvolt. The coaxial cavity was added to provide DC isolation for the preamp input. It's built in a Radio Shack six-inch chassis, with a partition which serves as one wall of the cavity and separates the cavity from the preamp. The LC newwork of the cavity is a 5½-inch piece of number 16 copper wire, grounded at one end and connected to the stator of a small variable capacitor at the other end. The rotor of the capacitor is grounded, forming an LC tank circuit. Coupling is done at the grounded end of the piece of copper wire, through grounded links 1¼-inches long, spaced ¾-inch from the LC tank (copper wire and capacitor). (See Fig. 16-3.)

The cavity itself will tune from about 190 to about 250 MHz. I don't know the value of the capacitor (it is a very small butterfly capacitor having three rotor plates and two stator sections of three plates each). I picked up several of these capacitors, and have tried leaving the unused stator unconnected, and removing it. It makes no difference to the tuning, as near as I can determine. The "Q" of the circuit is fairly good, with signals a few MHz away down 10 dB, with a distinct sharpening of the passband either side of center were down 20 dB, with the three-dB points being approximately 200 signals 5 MHc on kHz either side of center. I tried closer coupling of the input and output links (⅜-inch), and gained a couple of dB in sensitivity, but broadened the "skirts" of the filter beyond the point I felt was acceptable. I would judge that ¾-inch spacing of the input and output links from the tuned circuit is about right. I also tried wider spacing (1½-inch), but the insertion loss became prohibitive."

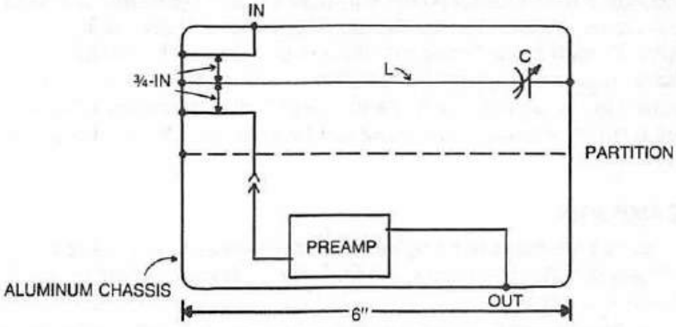
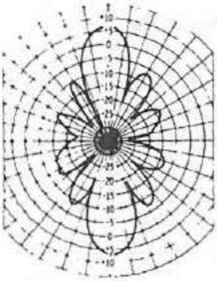


Fig. 16-3. A selective cavity for a 220-MHz receiver front-end.



Chapter 17
Boosting Transmitter Output

The following amplifier design has been around for some time. It was originally thought up in the mid 1960s by Larry Levy, WA2INM, and me, and has seen service in many modes over the years. At one time, I used this same amplifier design in AM-linear service, driven by a Heathkit Sixer transceiver with excellent results. The amplifier is capable of operating Class A, AB_1, B, or C, depending upon the bias setting. It therefore has the capability of becoming a functional addition to almost any VHF hamshack, and makes a very fine Class-C amplifier for relay-system use.

The tube chosen for this design was the venerable 6146B; a tube of proven performance in thousands of transmitters over the years. However, other tubes may be substituted—including some television horizontal-output sweep types—with little circuit change. One version of this amplifier, built in 1969, used a type 6DQ6/6GW6 with surprisingly good results, though not equal to the 6146B in VHF efficiency. See Tables 17-1 and 17-2 for parts lists.

The amplifier is designed around commonly available components, and nothing other than RFC-3 is critical. It is assumed that anyone undertaking the building of this, or any other VHF project is aware of proper VHF/UHF construction techniques, and will adhere to all principles of such. Though the 6146B is capable of a lot more output than this design will produce it was felt that taking a conservative approach would provide longer tube life. Therefore, I've selected a 40-watt power-input level, which yields approximately 32 watts of useful power output in Class-C operation. It is built in two sections, section A being the amplifier itself, and section B its power supply. Though no metering provision is included in the amplifier, a 250 milliamp meter can easily be installed in the plate voltage supply—as indicated in the power-supply diagram—to facilitate tuneup. Alternately, some form of temporary metering can be inserted during tuneup procedure.

THE AMPLIFIER

Many versions of this amplifier have been constructed, using a variety of chassis layouts. I will leave the final chassis layout to your descretion, with but two cautions:

- This amplifier design uses dangerously high voltages which can cause injury or death if you should inadvertently come in contact

Table 17-1. Parts list for the 6146B amplifier.

L_1/5½ Turns #16 enamelled wire ¾″ ID-Tapered 1½ Turns from ground end
L_2—4½ Turns #14 enamelled Wire ⅞″ ID-1¼″ Long.
RFC$_{1,2}$—Ohmitze Z-50 Solenoid Chokes
C_1, C_2—0-25 pF Air Variables
C_3, C_4, C_8, C_{11}—.001/1 KV Disc Ceramic Cap.
C_5—100 pF-6KV Disc Ceramic
C_7—.001/6KV Disc Ceramic
C_9—0-20 pF Air Variable-2KV Insulation
C_{10}—0-250 pF Air Variable—1KV Insulation
R-1—10Ω- Cut Carbon
J_1 & J_2—SO-239 Connectors
J_3—Chassis Mounted Octal Plug
C_N—See Text
RFC$_3$—See Text and Fig. 18-2

with them. You are advised to design a chassis layout and enclosure so as to prevent any chance of this occuring. Neither Tab Books nor the author assumes any liability or responsibility for any injuries or deaths occurring from your negligence in regard to the proper construction of this amplifier, the proper housing of it, or its use. It is your direct responsibility to exhibit proper caution when working with and around dangerously high voltages.

- Regardless of the final chassis layout you choose, all RF-input circuits must be shielded from all RF-output circuits by some form of shielding plate, connected to a low-impedance chassis ground. If this provision is not met, the amplifier will tend toward self-oscillation, and achieving proper neutralization will be impossible. For amplifiers built in a vertical plane, this means placing all input circuitry under the chassis and all output circuitry above the chassis. For amplifiers built in a horizontal configuration inside of a chassis box, this dictates partitioning the enclosure to provide two RF-tight compartments.

Input to the amplifier is through J1 (see Fig. 17-1) and is coupled to V1 by way of L1, C1, and C2. L1 is tapped at its 50-ohm point to provide proper impedance matching for the driver stage. C2 is the drive-coupling capacitor, and is adjusted to provide the proper drive voltage to V1. Since C2 is actually a part of the overall resonant circuit formed by L1, C1, and V1, its adjustment will interact with that of C1, and each time C2 is adjusted have will C1 to be readjusted for proper resonance. RF output from the plate of V1 is coupled to J2 through a tank circuit consisting of C9, C10, and L2. A P-Network configuration was selected since this tends to eliminate many unwanted harmonics. RFC3 is an anti-parisitic choke shown in Fig. 17-2 designed for VHF service. It is part of the copper plate-strap connect-

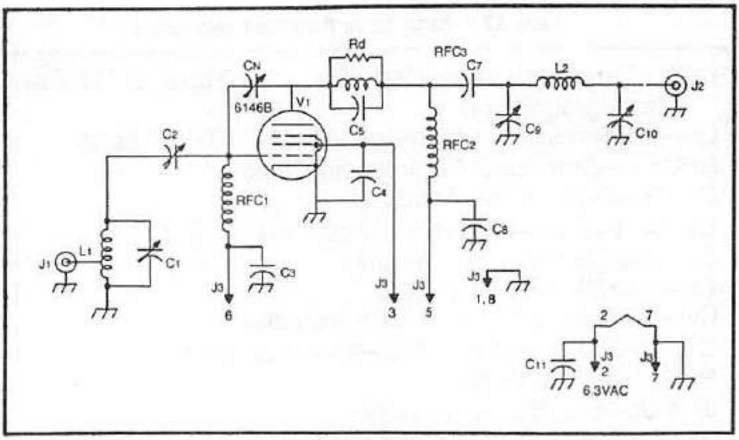


Fig. 17-1. Schematic diagram of the 50-MHz amplifier.

ing the junction of RFC2/C7 to the plate cap of the 6146B amplifier tube. It is constructed by soldering a 10-ohm, 2-watt carbon resistor across one side of the strap and a 100 pF 6 kV disc-ceramic capacitor across the other. Leads are kept short, and the bodies of these components tight against the strap material. The junction of RFC2, RFC3, and C7 should be of a material that will withstand high temperatures, high circulating RF currents, and high voltages. A 2 to 2½-inch ceramic standoff tapped at both ends to accept a 6-32 screw is ideal. One end can be bolted to the chassis, and a chassis lug attached to the other end to support and properly insulate this junction. Such standoff insulators are available from most surplus-parts dealers.

Table 17-2. Power supply part list for the 50-MHz amplifier.

PARTS LIST—POWER SUPPLY

T1- Replacement Color-TV power transformer - see text.
T2 - 6.3V - 2 A Filament transformer - see text.
D1, D2, D3 - RCA SK-3017 or equiv.
C1, C2, C3, C4 - 80 μF - 450 Volt DC electrolytic capacitors
C5 - 150 μF - 250 VDC tubular electrolytic capacitor
C6, C7, C8, C9, C10, C11 - .001 - 1KV disc ceramic.
FS1, FS2 - 5 Amp - 3AG type slo-blow fuses in insulated mounts.
FS3, FS4 - 1 Amp - 3 AG type fast blow fuses in insulated mounts.
FS5 - .75 amp - 3AG fuse - slo-blow| in insulated mount.
FS-6 - 20 Amp - *AG fuse in insulated mount.
V1 - Type VR-150 tube
R1 - 6.8 K - 20 watt wirewound resistor
R2 - 4.7 ohm - 10 watt wirewound resistor
R3 - 8.2K - 2 watt carbon resistor
VR-1 - 50 K - 5 watt potentiometer.
M-1 - Optional 0-250 milliamp meter

Miscellaneous:7 wire cable and socket to match chassis connector on amplifier, chassis, hardware, enclosure.

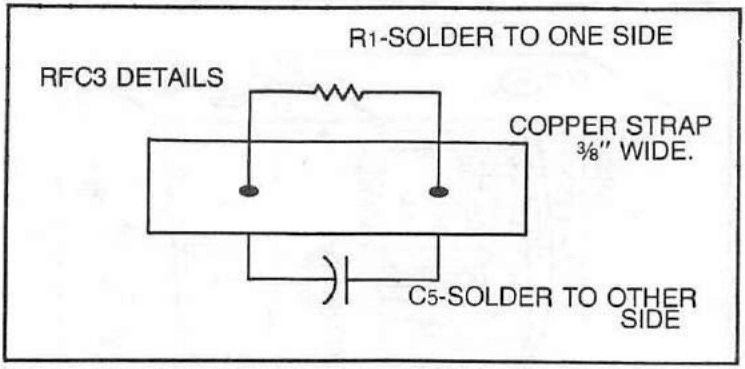


Fig. 17-2. Details of parasitic suppressor, RFC-3.

It is also advised that the output of this amplifier be fed through a good low-pass filter, such as an R.L. Drake TV-1000 LP, to clean up any unwanted harmonic content in its output. This will minimize any chance of either TVI or RFI.

POWER SUPPLY

Again the chassis-layout choice is yours, but the rules of safety prevail as before. Always keep them in mind when working with dangerously high voltages. The power transformer used in this supply was salvaged from a defunct Sylvania color-TV receiver, vintage 1967, as were many of the other components shown. This design uses a novel approach in developing two HV sources from one transformer winding. See Figs. 17-3 through 17-5.

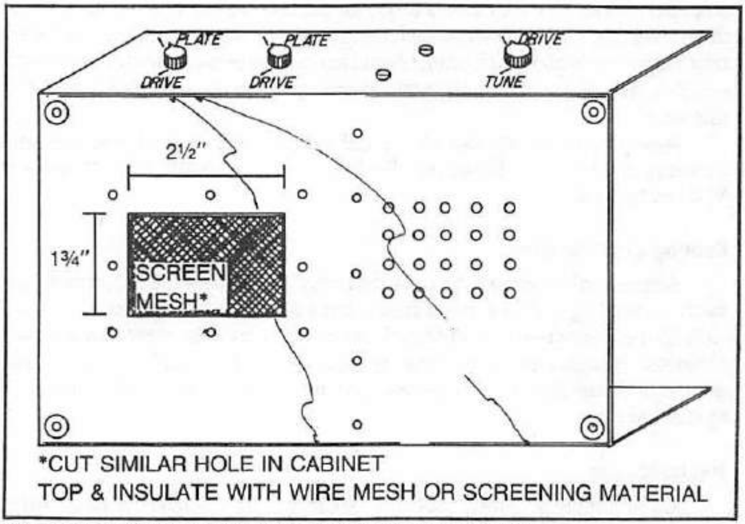


PLATE
DRIVE
PLATE
DRIVE
DRIVE
TUNE
2½"
1¾"
SCREEN
MESH*
*CUT SIMILAR HOLE IN CABINET
TOP & INSULATE WITH WIRE MESH OR SCREENING MATERIAL

Fig. 17-3. Bottom view of the enclosure for the amplifier.

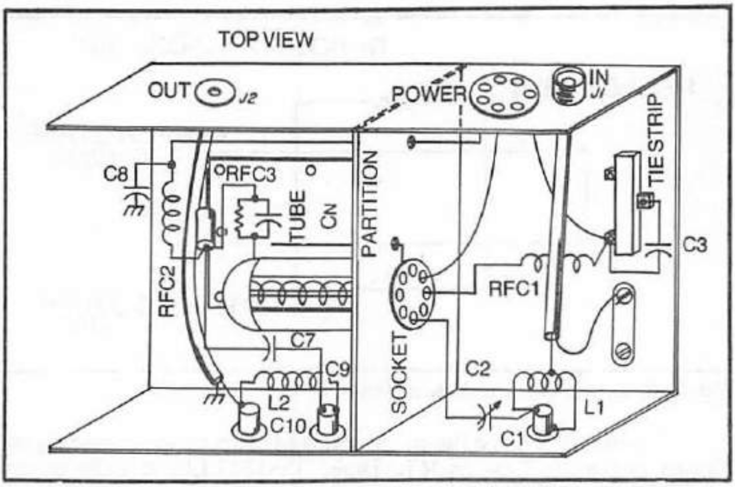


Fig. 17-4. Top view of the enclosure showing shield partition and component placement.

A full-wave voltage-doubler provides an output of approximately 400 VDC under load. The 150-VDC supply is derived by making half the supply serve double duty as a half wave rectifier, and tapping the half-wave point, further filtering it and regulating it.

Bias for the amplifier is derived by connecting a 6.3 V, 2A-filament transformer backwards. The primary becomes the secondary, and vice versa. Its 6.3-volt winding is connected across the heater supply and the voltage is stepped up in the secondary to about 120 VAC. This is rectified and applied through R1 to VR1, which sets the operating bias point for the amplifier. Virtually every line is fused for protection, including both sides of the power line. A provision is included for plate-current metering to facilitate easy tuneup and monitoring of operation. A seven-conductor cable with a socket (female) to match the male chassis plug on the amplifier completes this unit.

Any power supply capable of delivering the required voltages and currents can be used. However, final plate-supply should not exceed 400 VDC in this unit.

Cooling Considerations

Ample airflow should be provided over the 6146B tube. Normal convection coupling will do in most cases, but a small fan blowing air across the tube is recommended in confined areas such as repeater/remote rack cabinets. Remember, tube type amplifiers run hot, and it is heat that destroys components. You cannot provide "too much" cooling in relay-system service.

Neutralization

C_n is simply a 3-inch piece of No. 18 or 20 insulated hookup wire, soldered to the grid pin of V1 passed through a small insulated hole in the chassis, and let stand alongside the plate structure of V1. Never permit this wire to touch the plate cap of V1—or any components carrying high voltages—as damage to V1 can result. Amplifier neutralization is achieved by varying the distance of this "stub" from the glass envelope, thereby varying the capacitance coupling. An insulated tool must always be used in adjusting this stub, since it is near dangerously high voltages. *Never adjust it with your bare hands for any reason!* Normal amplifier-neutralization techniques and indications should be adhered to.

Drive Requirements

One to two watts of RF will drive this amplifier to maximum output with ease. Dissipate any excess RF in a pad between the exciter and amplifier to avoid amplifier damage.

Final Tuneup

Preset the bias to approximately-100 V at the junction of C3 and RFC1. Turn on the HV supply. Observe the plate-current meter, and readjust the bias control for 15 to 20 MA idle current. Apply 50-MHz drive from the exciter and observe the plate meter for increased plate current. When this occurs, immediately shut off the plate supply and remove drive (adjust C1 to obtain this indication if needed).

Connect the output of the amplifier to a 50 ohm, non-inductive load, capable of dissipating 50 watts of RF at 50 MHz, through a harmonic-attenuation filter and forward-power wattmeter. Preset C9 and C10 for maximum (plates fully meshed). Reapply, HV, and adjust C1 and C2 to provide 100 to 120 MA plate current. Immediately tune C9 for a dip in plate current, thus indicating resonance. Readjust C1 and C2 for maximum drive—but not exceeding 50 to 60 MA indicated final plate current. Note: *These adjustments must be made very quickly to avoid damage to the 6146B. If you take longer than 10 seconds, shut down the HV supply and allow the amplifier to cool for 2 or 3 minutes before continuing.*

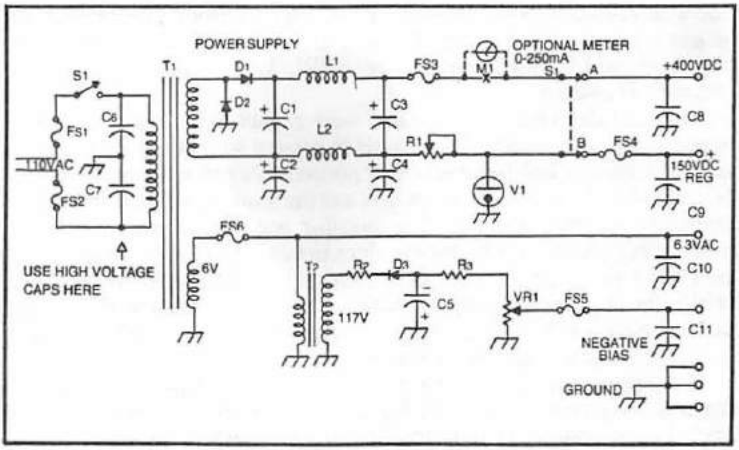


Fig. 17-5. Power supply for the 6146B amplifier.

Now tune C9 and C10 for maximum indicated output power while not exceeding 110 MA of plate current at resonance. If all conditions are met and everything is working properly, your power meter should indicate about 32 watts RF output. Once you are satisfied with the amplifier's operation, install it in your repeater system, or at your base station, and have fun.

THE ULTIMATE KICKER FOR TWO

How would you like to be "King of the Hill" in your sector, on two meters? You can be when using the amplifier to be described. This powerhouse can be driven to the full legal limit, using a 10 watt transceiver. It requires only two inexpensive surplus tubes. Just about everything in the amplifier was obtained from surplus, yet the results match the quality of the finest in commercial rigs. The tubes used are Eimac Y-791's. The Y791 is a selected 4CX300A, intended for 3000 volts on the plate. I don't even use the 2500 volts, which is the highest recommended for the 300A.

The 4CX300A is the bayonet-base improvement of the well known 4CX250A. It is an air-cooled, ceramic-based 300-watt plate dissipation type. Both the tubes and sockets are available surplus. A pair of these, with 2500. V on the plate, in the FM mode will produce 1000 watts into the antenna. I have four voltages available, 800 to 1800 volts, meaning I can run from 200 watts to approximately 700 watts output.

The basic circuitry of the amplifier is not new; the layout of the RF hardware, and the power supply are unique. The amplifier is in the push pull configuration and can be biased for single sideband or FM operation. See Fig. 17-6. The input grid coils consist of two half-wave lines coiled up and tuned to frequency with a 15 pF per section, ungrounded, split-stator capacitor. The capacitor is paralleled with a 5-pF butterfly or differential capacitor, used to balance the drive to the grids. The tubes are mounted in a horizontal plane so that they tie directly into the plate lines.

The plate circuit is made horseshoe shape, using solid sheet brass somewhat less then 1/16" thick. The horseshoe is overall 11" long and 4" wide with a cutout of 1 ⅛" × 9½". The tuning capacitor is fabricated from the same brass material. Both the plate lines and capacitor construction have been widely publicized in the ARRL *VHF manual* and *Radio Amateur's Handbook*.

The amplifier chassis and cabinet were rebuilt from what was once a commercial power supply. The chassis is divided so that the plate circuit can be completely isolated from other portions. Actually, there are three sections, as the grid side of the sockets and the associated circuitry are in a completely shielded housing. This housing not only isolates the input circuitry, but also is a highly efficient air chamber. The blower feeds air into one end of the chamber, the air passing through the tube socket and through the plate cooling mesh. The air further passes over the brass plate coil, cooling it, and it in return helps dissipate the heat on the plates of the tubes. All-in-all, the amplifier runs very cool.

Test points are provided for measuring heater voltage, which can be adjusted, and screen voltage. See Fig. 17-7. There are three meters on the panel. Two basically have 100 microampere movements. The meter on the left provides six functions controlled by a selector switch. These functions

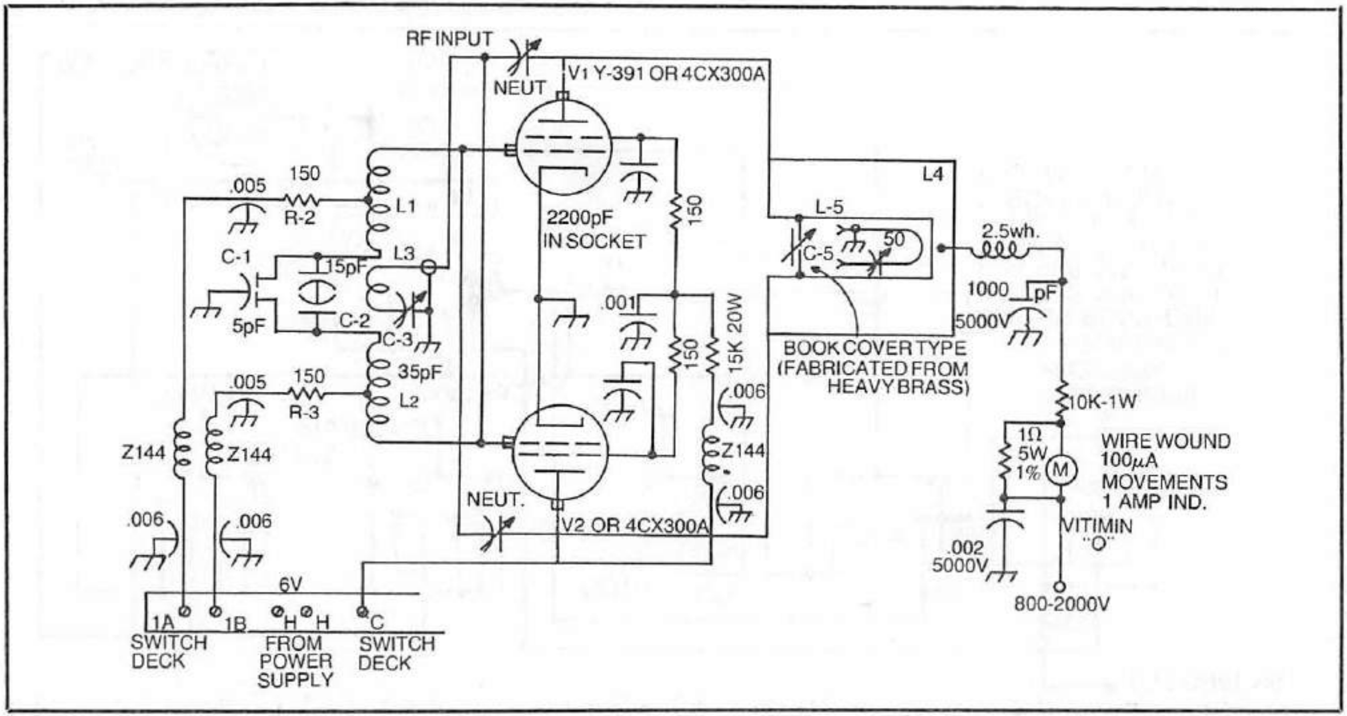


Fig. 17-6. Schematic diagram of the "Ultimate Kicker."

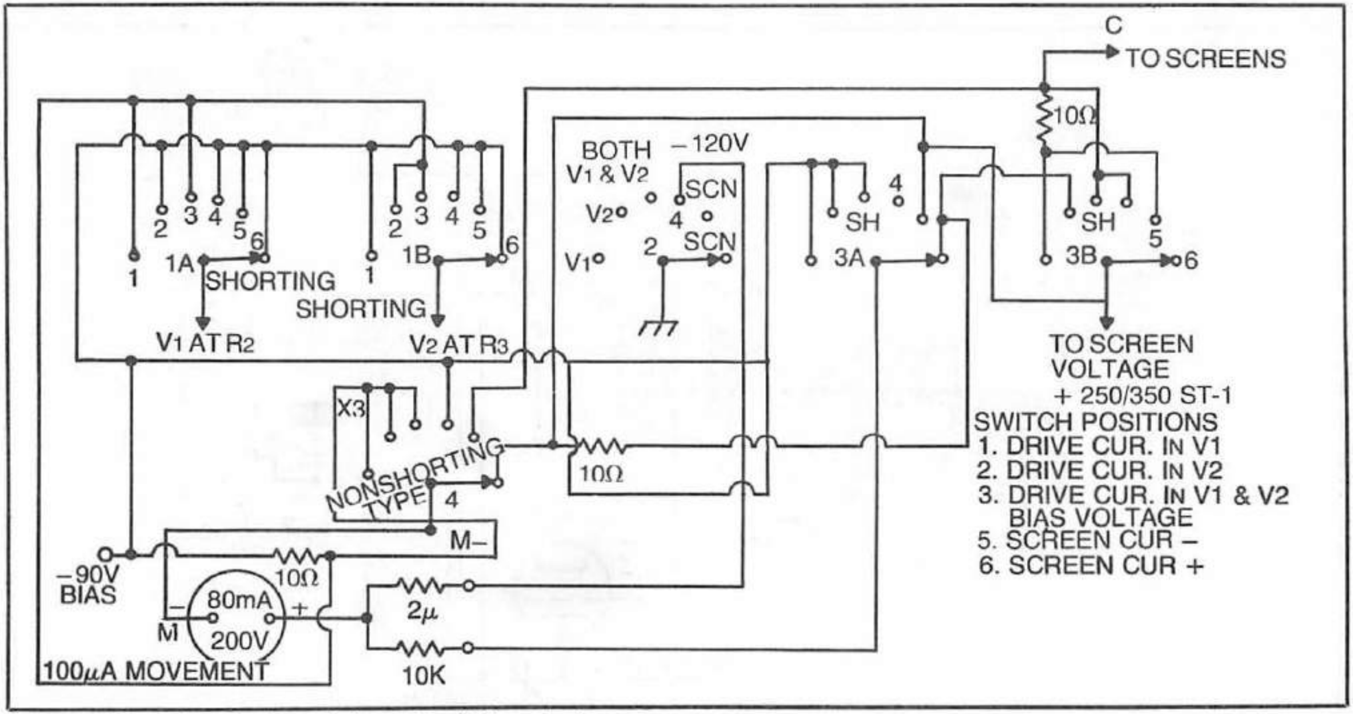


Fig. 17-7. Connections for the metering and switching circuit.

indicate input drive current for either tube separately or combined, and indicate bias voltage and screen current, either in the forward or reverse mode. The plate meter indicates a maximum of one ampere. Both meters are set up as voltmeters, with one volt being full scale. However, the scales indicate either voltage or current. The RF monitoring section contains the dream of all dreams, a built-in Bird wattmeter. A Bird directional coupler is included, and the third meter indicates power in either the forward or reverse mode, from which VSWR is easily calculated.

The Power Supply

The power supply actually took longer to build than the amplifier, as it had to approach the ultimate. The most difficult part about designing a supply for tubes is to come up with a good, stable, screen supply. This amplifier is not the first KW to be constructed by the author, or the first for two meters. Therefore many power supplies have preceded this one. Vacuum tube regulators have been used for screen regulation, as have VR tubes and high-voltage transistors. In this case I couldn't believe my eyes. When going through a surplus house, I found a box of goodies for $5.00, which contained among other things, over a dozen 50-watt, 110-volt TO-3 package Zener diodes. The problem was how to obtain both 250 and 350 volts by putting these in series. In both cases, it comes up short by about 25 volts. The thought occurred to obtain this voltage from the 28-volt DG relay supply, which could be increased to 31 volts (see Fig. 17-8). A 10-watt resistor would have to be placed at the bottom of the Zener string, and under the lowest screen current cycle (like zero), the voltage drop should

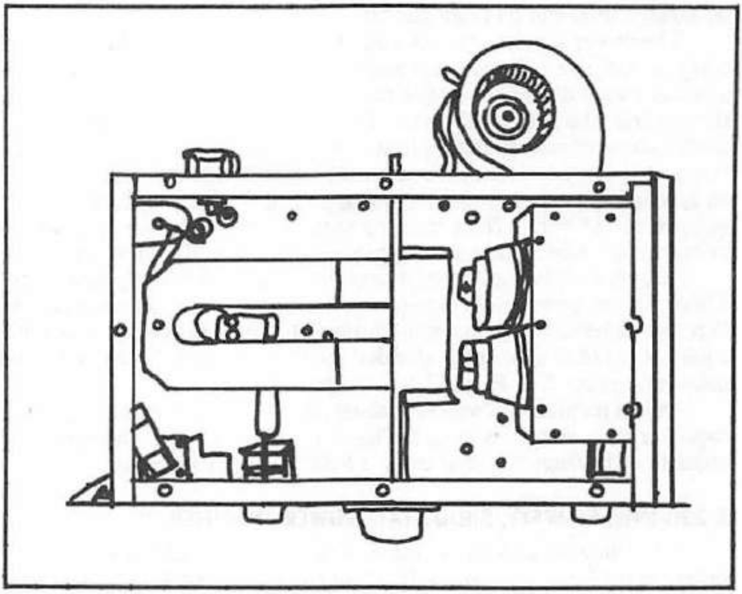


Fig. 17-8. Top view of the "Kicker," showing input circuit box and plate tuning arrangement.

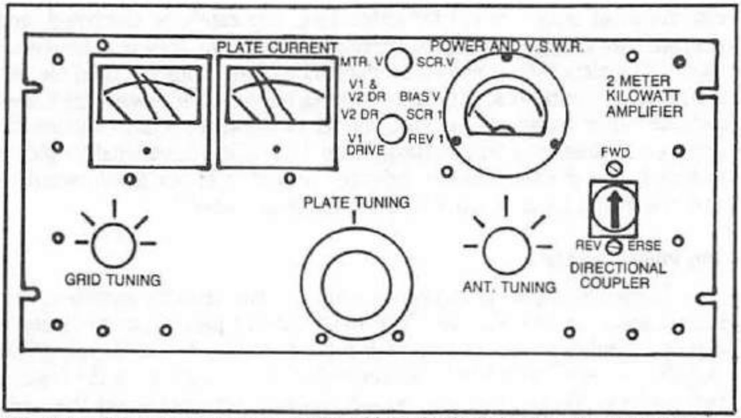


Fig. 17-9. Front view of the amplifier. Note the built-in directional coupler.

never get above about 23 volts. The results were total success: a beautiful 250-350 volt, solid, regulated screen supply.

An important note about power tubes: to apply screen voltage before plate voltage is total disaster, as the screen becomes a plate and begins to dissipate too much current. Screen protection is provided by means of a sensitive (12-32 volt) relay across a section of the plate-supply bleeder-resistor string. It becomes energized only when current is present in the bleeder resistor. The contacts of this relay, when closed, turn on the screen voltage. No plate voltage, no bleeder current; no bleeder current, no voltage drop and no relay pull-in.

The power supply panel contains seven switches, a pilot light, and the bias pot. A double-pole switch provides AC line power to the unit. There is a heater switch and a plate switch that are wired so that no matter which is thrown first, the heater will go on. There is a DPDT switch that connects the plate transformer primaries in series or parallel, thus allowing the plate voltage to be reduced for tuning purposes. There is a 20-A toroid, wound as an autoformer, allowing the line voltage on the plate transformer to be boosted to 148 volts. The remaining switches are for low or high screen voltage, and finally, a test switch that can also be used for CW operation.

Lastly, the RF amplifier contains two items not previously mentioned. There is a low-power and a high-power coaxial antenna relay connected so that the antenna feeds straight through to the transceiver when the amplifier is not in use, and a shielded module containing an RF activated solid-state relay. See Figs. 17-9 through 17-13.

Only a fraction of a watt is drained off the transceiver through a 1pF capacitor to operate this circuit. This is possible as the voltage amplifier consists of Darlington circuit using a PNP and NPN transistor.

A 220-MHz, 60-WATT, SOLID-STATE POWER AMPLIFIER

The following amplifier design is by Ron Whitsel, LM3AXV, and was originally published in "Cheese Bits," the publication of the Mt. Airy VHF Club, and "QRZ," the publication of the Rocky Mountain Radio League. It was supplied by Jim Labo, K0OST, and is reprinted with permission.

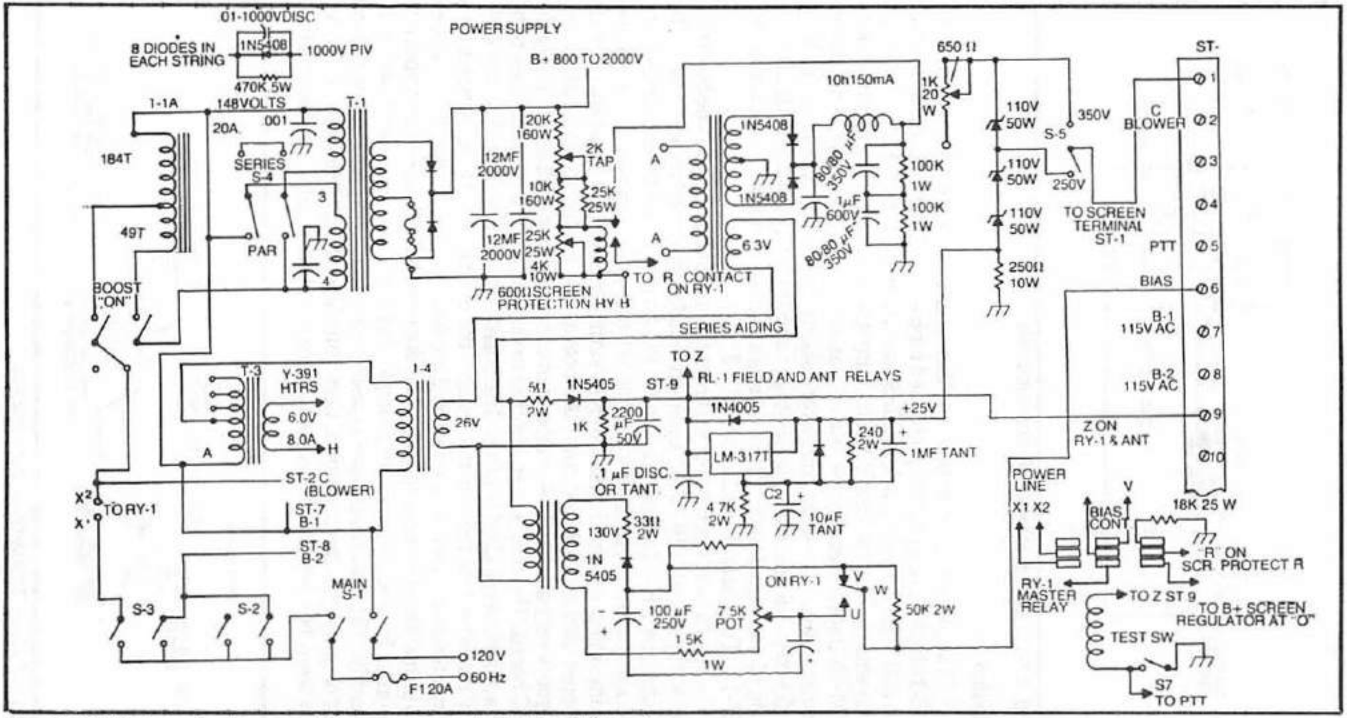


Fig. 17-10. Schematic diagram of the power supply for the "Kicker."

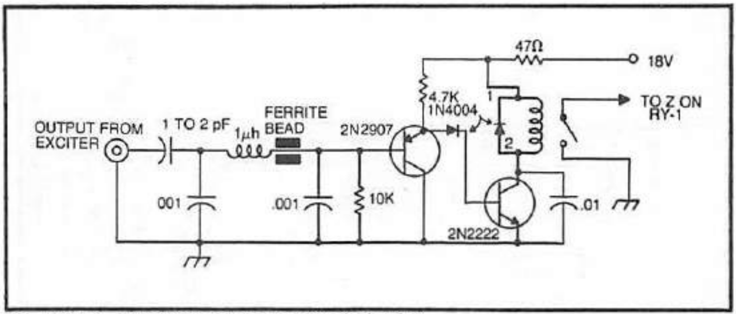


Fig. 17-11. Circuit for the RF-activated relay.

Device

The device used in this amplifier is a Solid State Systems (S.S.S.) DS-1416; a device primarily intended for use at 175 MHz, but it works well on 220 MHz with slightly less efficiency. At an input power of 120 watts, I was able to obtain at least 60 watts output with 12 watts drive from a Clegg FM-76 transceiver. By the way, I was able to get 70 + watts out on two meters, with the same transistor, slightly more drive, and about 60 % efficiency. All this with a single-stage amplifier! Only the 220 MHz information is presented here. The schematic for the amplifier is shown in Fig. 17-14. The parts list is in Table 17-3.

The circuit-board layout is shown full size in Fig. 17-15. The board is a 5″ × 2″ piece of 1/16″ glass epoxy material, copper clad on both sides. The technique I use for making simple PC boards is somewhat unique and requires a drill press and a 1/16″ or ⅛″ end mill. By mounting the end mill in the drill-press chuck. and carefully setting the depth of cut so that just the copper clad is machined from the board, one is able to duplicate simple layouts very quickly. I use rubber cement to attach the full size layout to the PC board. The tool is then lowered to the board, on one of the lines to be machined, and locked in place. The board is then maneuvered on the table so that the tool follows the outline on the layout. Once completing a circuitous cut, the tool is raised and the board moved so that the next area to be machined is under the tool. This is a very difficult procedure to put into words. In practice, it is very simple and produces a finished board very quickly. The remaining paper is peeled off easily, and a quick rub with steel wool completes the operation. Conventional etching techniques could also be used but be sure to leave the ground-plane intact. Another method

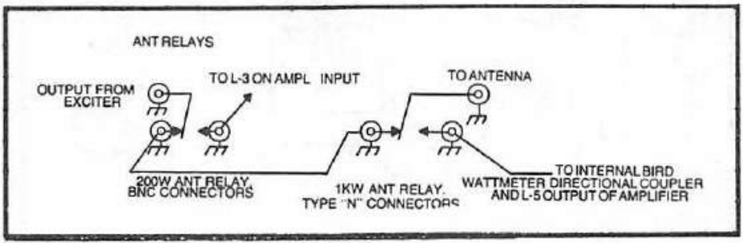

ANT RELAYS
OUTPUT FROM EXCITER
TO L-3 ON AMPL INPUT
TO ANTENNA
200W ANT RELAY, BNC CONNECTORS
1KW ANT RELAY. TYPE "N" CONNECTORS
TO INTERNAL BIRD WATTMETER DIRECTIONAL COUPLER AND L-5 OUTPUT OF AMPLIFIER

Fig. 17-12. Antenna-relay connections.

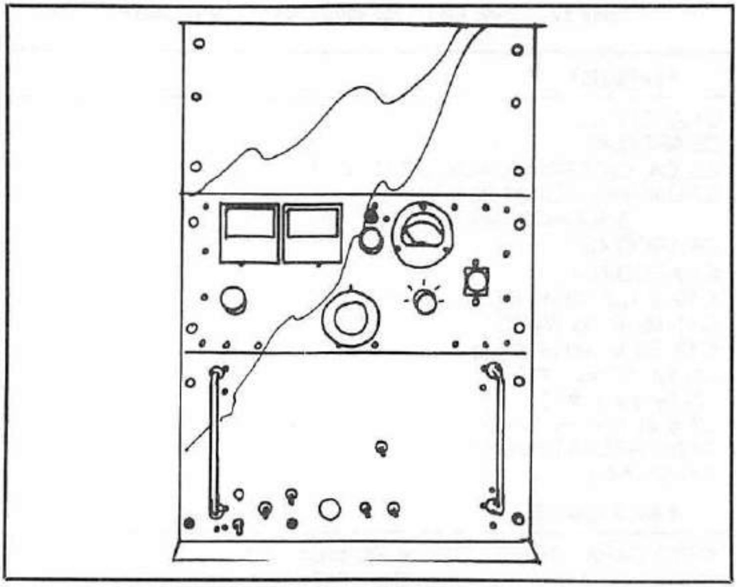


Fig. 17-13. The "Kicker" and its power supply mounted in the rack.

would be to make small "pads" or "islands" out of PC board material and attach them to the board to form isolated tie points for the components.

Circuit

The circuit as shown in Fig. 17-14 was taken directly from the S.S.S. data sheet for the DS-1416. New values for the tuned circuits were developed empirically for operation on 220 MHz. The only really critical

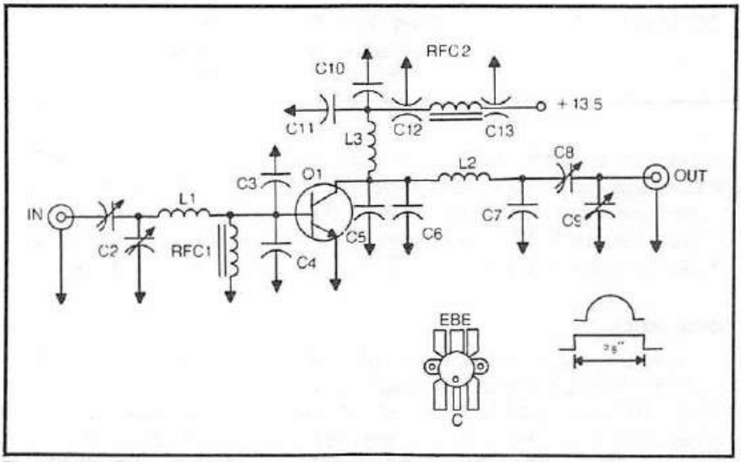


Fig. 17-14. Schematic diagram of the soild-state 220 MHz amplifier.

Table 17-3. Parts list for the solid-state 220-MHz amplifier.

PARTS LIST

C1-ARCO 423
C2-ARCO 421
C3, C4, C5, C6-Underwood J-101-22 pF
C7-Underwood J-101-22 pF or
ARCO 423 (see text)
C8-ARCO 423
C9-ARCO 404
C10 .0.1μF 30 WVDC
C11-10μF, 30 WVDC
C12, C13- 100 pF Feed-thru
L1- ½t, ½"dia., #12
L2- ⅝" long, #12
L3 = 4t. No. 16, ⅛" ID
RFC1, RFC2-VK-200 Choke
Q1- SD-1416

PARTS SOURCE

ARCO CAPACITORS :	Circuit Specialists Inc. P.O. Box 3047 Scottsdale, AZ 85257	
UNDERWOOD CAPACITORS:	Webster Radio Inc. 2602 E. Ashlan Ave. Fresno, CA 93726	J-101 @ $1.75
RFC1 & RFC2 :	Palomar Engineers Box 455 Escondido, CA 92025	Wide-Band Chokes @ $.80
SD-1416:	Solid State Scientific, Inc. Montgomeryville, PA 18936 Phone: 215-855-8400	

components are C3 thru C6. These capacitors are used in areas of high RF current, and require devices capable of surviving the environment. Don't compromise. Sources for some of the components are shown at the end of the parts list, Table 17-3. (More constant output was obtained with a 22 pF Unelco capacitor in place of C7. This modification is recommended.)

Construction

Construction is straight forward, and requires only that one follow good VHF circuit-building techniques. Component placement is shown in Fig. 17-16, and should be followed rather closely. The input and output connections were made on small ceramic stand-offs. Coax cable can be brought to these points and the braid soldered directly to the ground plane.

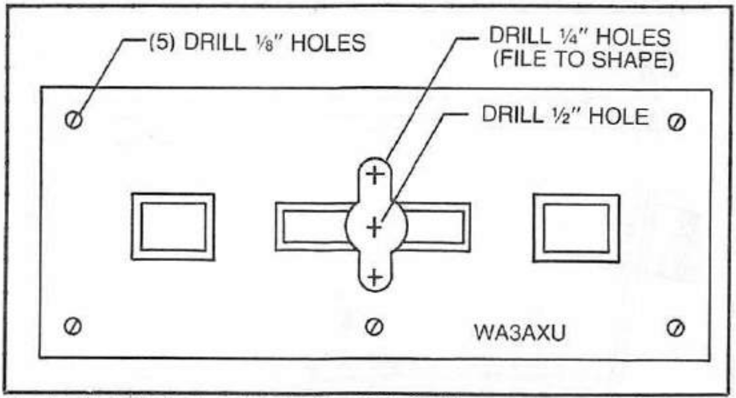


Fig. 17-15. Full-size template for the 220 amplifier.

Heat Sink

The amplifier requires a rather large heat sink to dissipate the unused power (60 watts). To be conservative, and to account for real world effects, I chose a heat sink with a thermal resistivity of about 1 ° C/watt. A heat sink that meets these requirements is 7 " long by 5 " wide and about 1 " high, including fins. Consult the catalogs to obtain precise thermal resistence values for the heat sink you use. Thermal compound is used between the transistor and the heat sink. Matching mounting holes are drilled and tapped in the heat sink to facilitate mounting. Full details for mounting the amplifier and its heat sink in an enclosure are shown in Fig. 17-17.

The Enclosure

The enclosure chosen for this project was a *Bud* model CU-347 die-cast aluminum utility box. This particular box has several distinct advantages; it is rugged in construction and is relatively RF tight when the cover is in place. Also, because it is a metal casting, it has substantial mass which contributes to the overall heat-sink effect.

The CU-347 was chosen over some smaller versions to allow room within the enclosure for the mounting of coaxial relays and a small pre-amp, which will be discussed later.

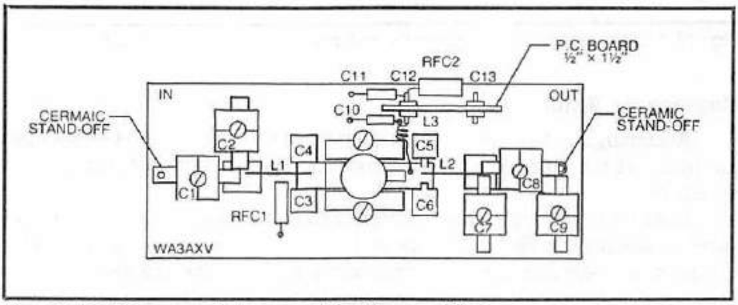


Fig. 17-16. Component placement for the amplifier.

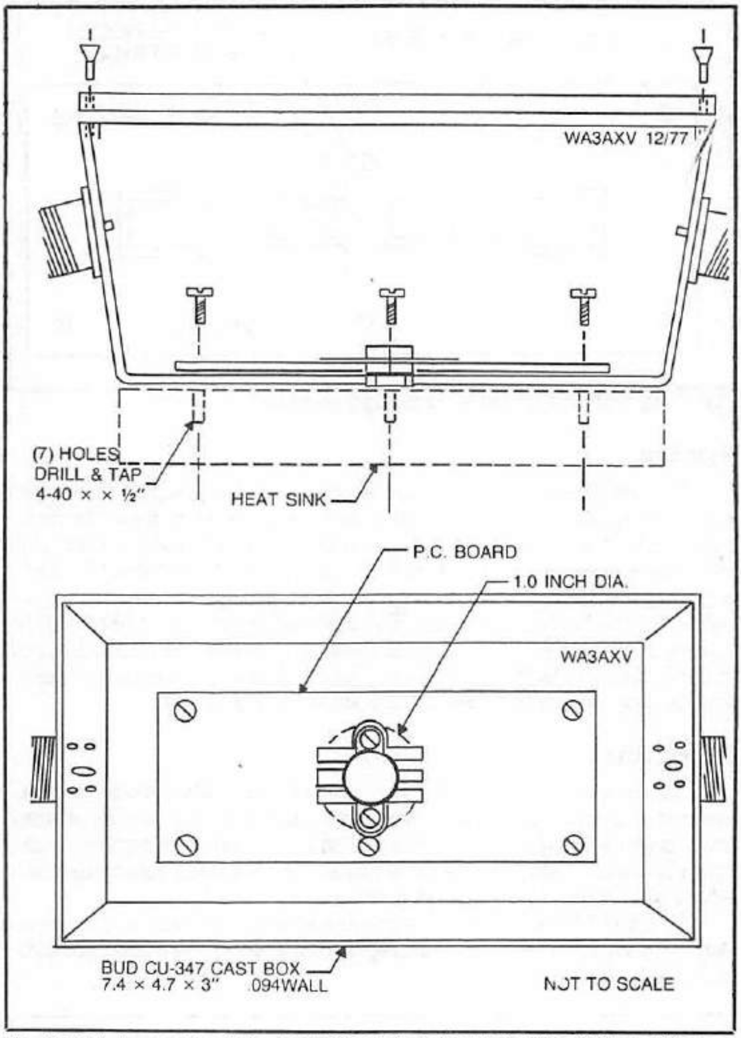


Fig. 17-17. Assembly of the heatsink and enclosure for the 220 amplifier.

Mounting the Board

Assuming the basic amplifier was constructed as described, mounting the board in the enclosure is very easy and results in a neat, integrated assembly.

Start by locating the exact center of the bottom surface of the enclosure. At this point make a 1" diameter hole with a chassis punch. This hole will provide clearance for the mounting flanges on the transister. Now locate and drill through the five mounting holes for the PC Board. Use the PC board as a template. Place the heat sink into position on the bottom,

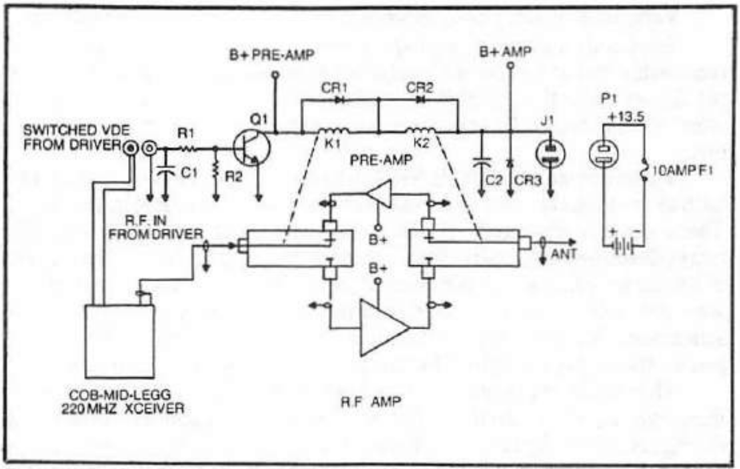


Fig. 17-18. Circuit for input-output switching of the amplifier.

outside surface of the box. Locate the mounting holes once again and drill and tap threads in the heat sink. Locate the transistor mounting holes and drill and tap.

Referring to Fig. 17-17, you will see that the bottom of the box, the PC board, and the heat sink form a "sandwich" that is held together by the five mounting screws. No spacers are required, since the thickness of the Bud box exactly equals the flange thickness on the transistor. If you use an ordinary aluminum chassis for an enclosure, you will have to provide the appropriate spacers to assure alignment of all surfaces. Use thermal compound between the transistor and the heat sink.

In actual use, the entire box will be turned upside down so that the heat sink is on the top. Input and output connections should be chosen to match your individual requirements.

Switching

Figure 17-18 shows the schematic for the switching circuit finally settled on for this project. Several other methods were tried, but proved to be marginally satisfactory at 220 MHz and 60 watts of power. Table 17-4 is the parts list.

Open-frame relays presented considerable mismatch to the exciter and to the amplifier output. (Don't forget the 220 MHz transceivers have SWR sensing circuits that reduce power if they see a bad match).

Table 17-4. Switching circuit parts list.

PARTS LIST	
R1, R2	-2.2K ½W.
C1, C2	-.001 μF
CR1, 2 3	-1N4005
F1	-10 amp. Fast Blow
J1	- "Jones" Jack, male
P1	-"Jones" Plug, female
O1	-2N4922
K1, K2	-Coaxial Relay, 6VDC, 20 ohms Res. Motorola Pt. No. 280C1017 or sim.

Various open-relay designs were tried but all had the same problems.

Solid-state switching techniques were also tried and seemed to work reasonably well at low power levels, but at 60 watts, severe heating in the pin diodes made this method unsatisfactory. Perhaps some development work in this area could produce a workable circuit (i.e., multiple diodes, etc.).

The arrangement that worked the best proved to be two coaxial relays such as are found in many of the old (and new) commercial FM transceivers. These devices are usually 6 VDC relays and of rather high quality. The relays described in the parts list were made by or for Motorola, but any unit of similar specifications could be used. If 12 VDC models are found, simply wire the coils in parallel rather than the series connection shown in the schematic. Transistor Q1 is not critical. Any general purpose NPN that will handle the current required by the particular relays used will work.

The coaxial relays are connected as shown in Fig. 17-18 so as to switch the power amplifier into the circuit when transmitting and out of the circuit during reception. A pre-amp is shown in the schematic and may be replaced by a piece of coax if it is not used. Switched B+ for a pre-amp is also indicated on the schematic.

The "cob-mid-legg" family of transceivers (all identical) have a Jack on the back which, among other things, provides switched 12 VDC: ON when transmitting - OFF when receiving. Connection of this signal voltage to the circuit described above provides the necessary control of the amplifier. (Caution: If you use the pre-amp make sure the switching circuit is operational).

Tune-Up

Tune-up will require a VHF watt meter (Bird), ammeter, 13.5 volts at 8 amps, dummy load, and about 2 lbs. of patience.

First, the input network is tuned for minimum VSWR. With no voltage on the amp, apply drive from the exciter (12 watts) and alternately tune the input capacitors (C1 & C2) for minimum reflected power. Close to unity match should be achievable. The tuning will change when B+ is applied, but his procedure will get you close.

Next, install an ammeter between the power supply and the amplifier. Apply power, and check to be sure no current is indicated when no drive is present. If there is current, check for shorts. The output of the amplifier should be connected to the dummy load through the watt meter. The watt meter is not required on the input anymore, but if you have two it is nice. Reduce the B+ on the amplifier to about 10 volts and apply drive. Peak the output capacitors for maximum output. Do this quickly and keep an eye on the current. Now go back and peak the input capacitors for maximum output. Once you have everything peaked, go back to the output capacitors and retune them so that a condition of maximum output power and minimum current occurs. You will find there are tuning conditions which produce maximum power, but draw large amounts of current (just like the old tube days, eh?!). This is where you will use the two pounds of patience.

Finally, raise the voltage to 13.5 volts, and tweak the tuning once again to obtain the conditions described above. When you are all done, collector current should be 8-9 amps with 55 to 65 watts output. A small fan on the heat sink will keep things cool during the tune-up process.

DC Power Wiring

Since this amplifier requires about 8 amps, some special consideration should be given to the 12 VDC wiring in the automobile. It is strongly recommended that connection be made directly to the battery when making the mobile installation. A relay, controlled by the ignition switch, can be used to turn power off and on. Power to transceiver can also be provided by this arrangement. Please use appropriate *fast* blow fuses when making your installation.

Final Tune-Up

Once the amplifier package is completed and tuned on the bench as described, it is ready for mobile use. If you use a rear-deck mounted antenna, a good place for the amp is in the trunk. It may be left in the car all the time if the installation is made as previously described (The use of the pre-amp in the circuit, close to the antenna, results in exceptional receiving sensitivity).

All that now remains is to touch-up the tuning, to compensate for new cable lengths, and perhaps an antenna that is not quite 50 ohms. It is not a bad idea to temporarily connect an amp meter and watt meter to check performance as described under "Tune-Up."

THE SST A-1 VHF AMPLIFIER

SST Electronics of Lawndale, California, produces a neat little 1-watt in for 10-watts out, 2-meter power amplifier. The design is simplicity itself, and tuneup is quick and easy. A complete set of parts for this amplifier is available from SST Electronics, P.O. Box 1, Lawndale, California 90260. However, if you want to build the unit from parts on hand, SST has graciously permitted us the right to reprint their step-by-step assembly instructions, along with pictorial and schematic diagrams.

Introduction

The SST A-1 provides 15 watts output with 1 watt of drive (with a maximum of 3 watts drive), across the entire 2-meter band, without retuning. The A-1 is short- and open-circuit protected, and will not be damaged by high SWR.

Assembly Tips

- Use a low-power soldering iron (25-35 watts).
- Keep leads as short as possible.
- Clean the leads for best soldering of connections. Also clean the iron periodically.

Assembly

Mount the printed circuit board to the heat sink, using four flat spacers and four screws. See Fig. 17-19A. Before tightening the screws, be sure the power-transistor leads align with the printed circuit board. If the leads match up to the circuit traces, then remove the transistor and tighten the screws holding the board to the heat sink.

Mount the power transistor through the hole, with the thick and thin leads matching the correct sized strips on the PC board. Make sure that the leads stay aligned while you tighten the hex nut holding the transistor. Caution: tighten the hex nut until it is just snug. Overtightening can damage the transistor.

If you feel that silicon grease is needed to aid cooling, apply it to the threads and bottom plastic portion of the transistor before mounting. It has been our experience that silicon grease is not needed with this amplifier and heat sink for normal applications.

Solder the transistor leads into place, being sure to solder all the way around the tabs for best RF conduction. Do not overheat the transistor.

Mount the output transformer (T1) so that the center pigtail points toward the transistor, with the side leads on the pads on both sides of the collector, see Fig. 17-19B.

Mount and solder C4, being careful to observe polarity (+ terminal goes to the +12 V pad.

Mount and solder C2. Note that the movable-plate connection goes to ground.

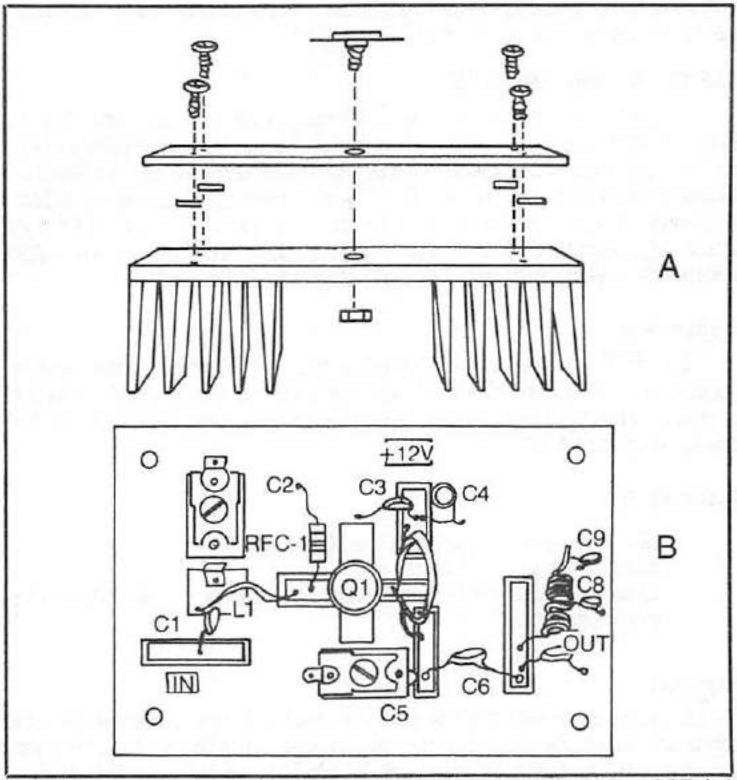


Fig. 17-19. Heatsink assembly, A, and parts placement, B, of the SST A-1 amplifier.

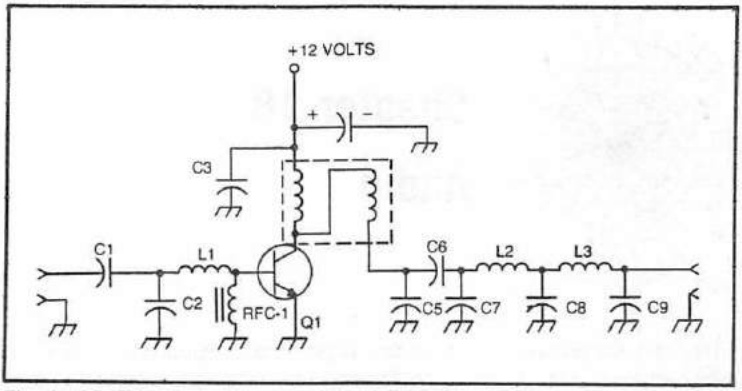


Fig. 17-20. Schematic diagram of the A-1 VHF ampliifer.

Solder in C1, L1, and RFC1.

Mount and solder C5. Again, be sure that the tab for the movable plate goes to ground.

Solder in C6. Parts L2, L3, C8, and C9 make up the output filter circuit. L2 and L3 are supported by C8 and C9 going to ground. Cut and position the leads of C8 and C9, then solder one end of L2 to the output terminal. Solder one of C8's leads to the junction of L2 and L3, and the other end to ground. Solder one of C9's leads to the other of L2 and the other C9 lead to ground. L2 and L3 are one piece of stock.

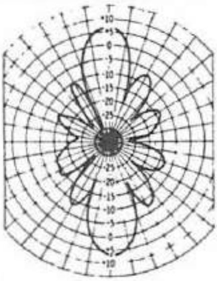
The input coax will connect between the input pad and ground. The output coax will connect onto the end of L3 and ground. Carefully check all solder connections. Be sure that there are no shorts or solder bridges between the PC pads.

Table 17-5. Parts list for the SST A-1 amplifier.

C1—12 pf. silver mica 120J
C2—Number 406 ARCO trimmer
C3—.01 ceramic
C4—47 mfd. electrolytic
C5—Number 406 ARCO trimmer
C6—100 pf. silver mica 101J
C7—12 pf. silver mica 120J
C8—22 pf. silver mica 220J
C9—12 pf. silver mica 120J
L1—Half-loop coil
*L2—3½ turn open air coil
*L3—3½ turn open air coil
*L2 & L3 are on one stock
T1—Output xfmr bifillar wound 3 terminal
RFC1—.47 uH molded body with color bands
Q1—TRW PT 5757 Power Transistor
D1-D4—4-40 × ¼" screws
D4-D8—flat washers
D9—8-32 Hex nut
1—Heat sink
1—PC board drilled and solder plated

Connect the output of the amplifier through a wattmeter to a dummy load, and connect a low-power transceiver to the input. Key the transmitter, and tune the two variable capacitors for maximum output on the wattmeter.

Figure 17-20 is a schematic diagram of the amplifier, and Table 17-5 is a parts list.



Chapter 18

Audio

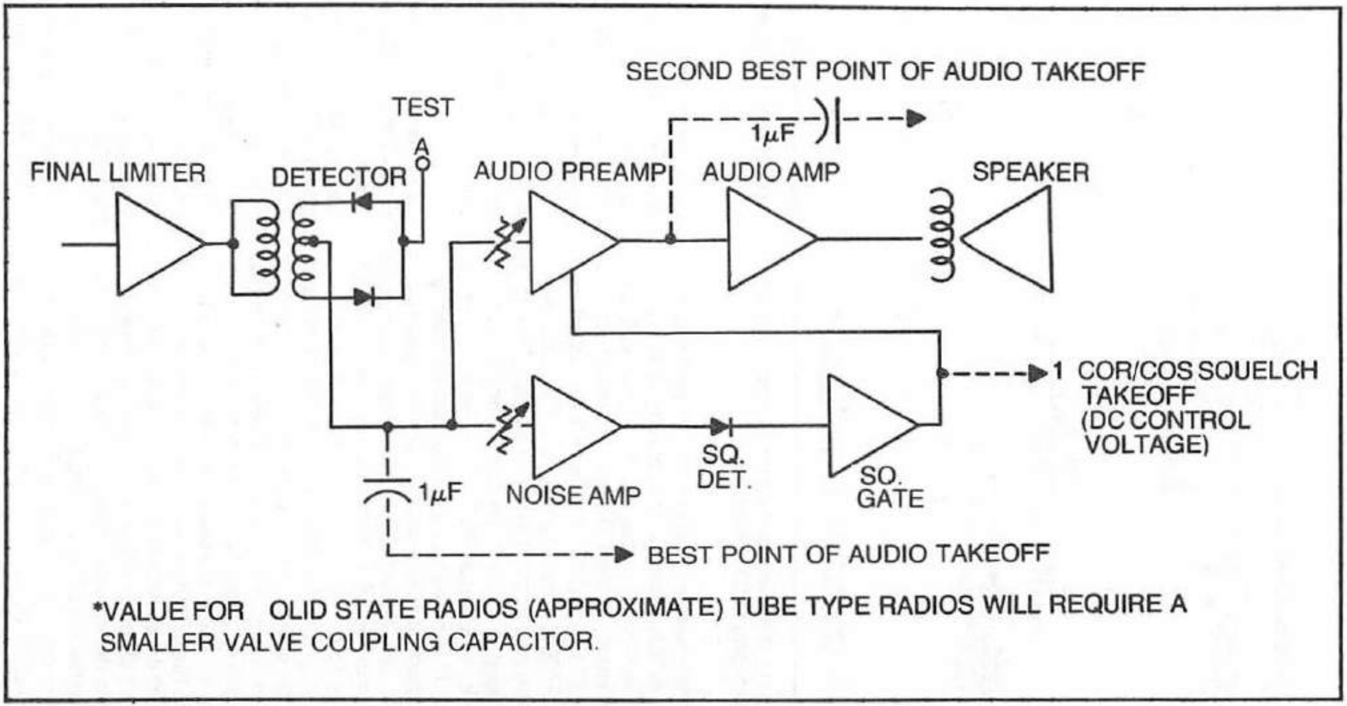
In the end, the purpose of any amateur repeater is to extend the range over which amateurs can exchange intelligence. In most cases, this means voice communications, and this leads us to the topic of audio. Moreover, it leads to a discussion of how to keep one's repeated audio sounding good. After all, the name of the game is to relay what the receiver hears in a manner that does not distort the quality and thereby render the relayed information useless.

GOOD AUDIO

Good quality repeated audio is not that difficult to obtain if you know some of the tricks. What we want is to find a spot in our receiver from which we can steal good-quality recovered audio, and then route this audio to our transmitter. Obviously, there are several places that will supply an audio signal, but only one point will give us really high quality: the output of the detector circuit. There are three basic detectors in use today. They are the Foster-Seely Discriminator, the Ratio Detector, and the Quadrature Detector. You will have to consult the service manual on the radio you have chosen for repeater use to determine which detector it uses, and where to pick off the audio. Let's call this point 2, as shown in the block diagram of a typical FM receiver, Fig. 18-1.

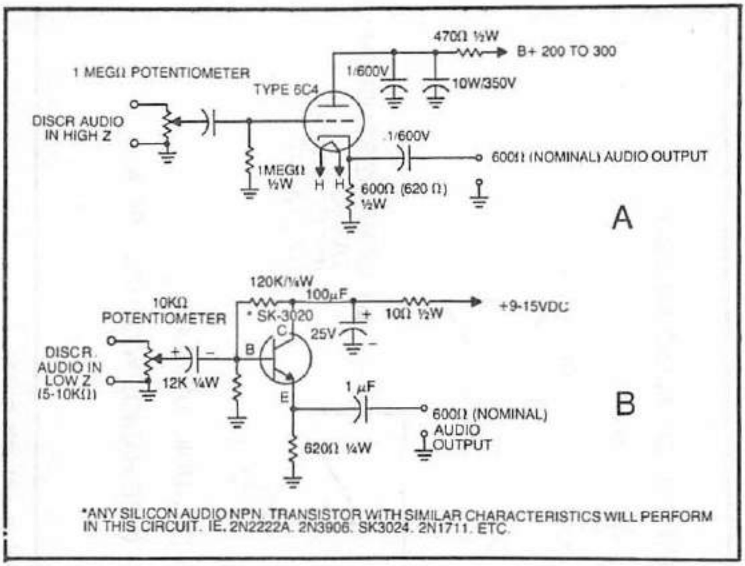
The audio level at this point will be quite low, anywhere from 20 to 200 mV. You will want to isolate this audio from the rest of the receiver circuitry, and transform its circuit impedance to some more useful level. I prefer either 600 or 150 ohms. The advantages of using low-impedance audio wiring is that there is less susceptibility to stray-hum pickup, and easier interface with transmitters, since most are designed to accept a nominal 600-ohm audio input. Tube-type equipment will require a cathode follower, while solid state will use an emitter-follower circuit for this purpose. Both are shown in Fig. 18-2, and each circuit contains a built-in level control to permit adjustment of repeated audio level separately from deviation adjustment. The output of the follower circuit is designed to directly feed the low-impedance microphone input of most FM transmitters. Use of this circuit, or one like it, will give excellent quality repeated audio, or, the output of the follower can be connected to the transmitter through some form of audio processor to enhance the overall level of repeated audio while still maintaining quality.

What about squelch action? If audio is derived directly from the detector there will be no squelch action and noise will be transmitted during


SECOND BEST POINT OF AUDIO TAKEOFF
TEST
A
1µF
FINAL LIMITER
DETECTOR
AUDIO PREAMP
AUDIO AMP
SPEAKER
1 COR/COS SQUELCH TAKEOFF (DC CONTROL VOLTAGE)
SQ. DET.
SQ. GATE
1µF
NOISE AMP
BEST POINT OF AUDIO TAKEOFF

*VALUE FOR OLID STATE RADIOS (APPROXIMATE) TUBE TYPE RADIOS WILL REQUIRE A SMALLER VALVE COUPLING CAPACITOR.

Fig. 18-1. Block diagram of typical FM receiver, showing tap-off points for audio and squelch information.



*ANY SILICON AUDIO NPN. TRANSISTOR WITH SIMILAR CHARACTERISTICS WILL PERFORM IN THIS CIRCUIT. IE. 2N2222A. 2N3906. SK3024. 2N1711. ETC.

Fig. 18-2. A cathode follower, A, and an emitter follower, B, circuit for audio interfacing to 600-ohm lines.

carrier-tail time. This presents no problem; it is a simple matter to short out the repeat-audio line and thereby mute it when no signal is present. This can be done by connecting the repeat-audio line directly across a spare set of contacts on the COR relay, or by activating a separate relay from either the COR or COS. Action will be instantaneous as determined by the COS/COR time constant, and the audio will mute as soon as a carrier disappears from the receiver's input. This circuit, shown in Fig. 18-3, was developed originally for use in the WA2ZWP repeater in Brooklyn, New York, which used RCA LD series radios for RF hardware.

If you wish to use the radio's internal squelch circuit to provide inter-transmission muting, then the point you want to look for is either the plate or collector of the audio stage controlled by the squelch gate. Again refer to Fig. 18-1. As you can see, we are trying to tap audio from a point as close to the detector as possible. A good rule of thumb to remember is: "The farther along the audio path we go, the more distortion will be present in the audio." Here, again, either a cathode or emitter follower will be needed to transform the impedance to something usable with our system. However, it may be necessary to swamp the level and then shape the audio to restore it to the quality obtained at the detector. In this, experimentation with the individual radio will be necessary. Another factor is that the radio's original volume control will now serve as the repeat-audio level control, and this will mean additional circuitry to provide for on-site local monitoring while the system is being serviced or under local control. Also, depending upon the overall audio circuitry of the radio, the monitor level may be quite low in relation to the normally expected level, because, once set for repeat operation, the radio's volume control can not be used to adjust local monitor

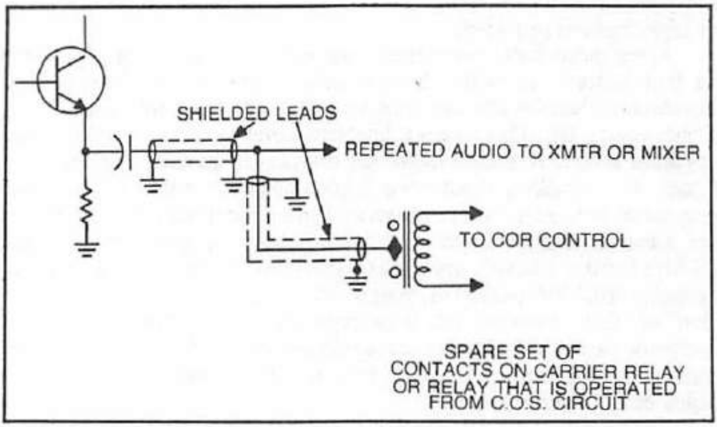

SHIELDED LEADS
REPEATED AUDIO TO XMTR OR MIXER
TO COR CONTROL
SPARE SET OF CONTACTS ON CARRIER RELAY OR RELAY THAT IS OPERATED FROM C.O.S. CIRCUIT

Fig. 18-3. Audio connections to repeater transmitter and a method of eliminating the squelch-tail by means of spare relay contacts.

level. The additional monitor circuitry is approximated in Fig. 18-4. However, exact circuitry and component values will depend upon the particular receiver. Use this information only as a guide.

THE TRANSMITTER

We have now located our audio and transformed it to an impedance of our choosing. Now it's time to take a look at the transmitter end of things. Many Amateurs tend to confuse deviation with audio level. Probably because most amateur transceivers have but one audio adjustment, that being deviation. While this might suffice for a mobile or base radio, it is not good practice to use a deviation control for setting repeat audio level. The deviation control should be preset to provide the desired deviation level and locked into position. To be more specific, it should be used to set the absolute peak deviation and nothing else. A separate audio-level adjustment should be used, at an earlier point in the audio chain, to provide system

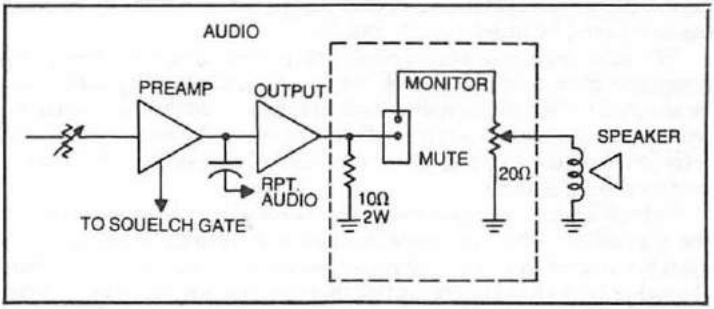


Fig. 18-4. A squelch-gated circuit for repeated audio, with provision for on-site monitoring (shown inside dotted outline).

audio-level adjustment. If the follower circuits I've outlined are used, such an adjustment is provided.

Along these lines, never trust your ears—or the ears of anyone else for that matter. No matter how accurate someone will claim to be in adjusting modulation and deviation by ear, there is no substitute for the proper equipment. This means a deviation meter or service monitor with a deviation scope. A simple devscope diagram is given in the appendix. Again, we are talking about being a good-neighbor, and it is your direct responsibility to adjust your system's audio so that it will not interfere with any adjacent channel activity. In areas where right-side-up, split-split 15-KHz tertiary channels are used on two meters, this means a maximum deviation of 4.5 kHz peak! Yes, your users will tell you that the audio sounds "low" or "thin," however, that is the price you will have to pay to exist at all in crowded areas. All adjustments should be made with the help of the best equipment you can purchase or rent, and these adjustments should be repeated on a periodic basis.

The best procedure to follow is to connect the transmitter to a dummy load, sample the RF into a service monitor, set the deviation control to the absolute peak permitted by local standards, and then set the average audio-level with the modulation-gain control that you have installed. When making the deviation adjustment, the gain, or modulation-level, control should be set to maximum and a known stable signal source, such as an audio generator or audio oscillator with calibrated output, should be used for the adjustment. Always follow the manufacturer's suggested setup procedure.

After all adjustments have been made, it's time for the smoke test. The purists will disagree with this procedure, however, it's one that has proven itself over the years. Using a local radio that has been properly adjusted for maximum peak deviation, and with the repeater transmitter and the radio connected to dummy loads, depress the PTT button on the radio and literally shout into the microphone. Observe the pattern on the scope or service monitor. It should look distorted and clipped, but it should not show any peaks past the preset peak level. If it does, go back to square one and repeat the alignment procedure until you achieve a condition wherein there are no peaks past the preset maximum level. I freely admit that this is far from the most scientific approach, however this system has proven itself time and time again over many years, on many systems, and has been used by many system owners.

If, after adjusting your system for proper deviation, you receive complaints from your usership of "weak" or "thin" sounding audio, do not be tempted to "up" the deviation level to satisfy them. You will be creating more problems than it's worth. Rather, use one of the audio-enhancement techniques outlined in chapter 20 on "Audio Processing," and leave the deviation control alone.

One final item. We have discussed coupling audio from the receiver to the transmitter while assuming a single-site system. However, if the system operates split-site, that is, receiver at one location and transmitter at another with a wireline connecting them, then there are other considerations to contend with. The most prevalent is line loss. The circuit in Fig. 18-5 will help overcome this problem. It uses a single LM-386 integrated

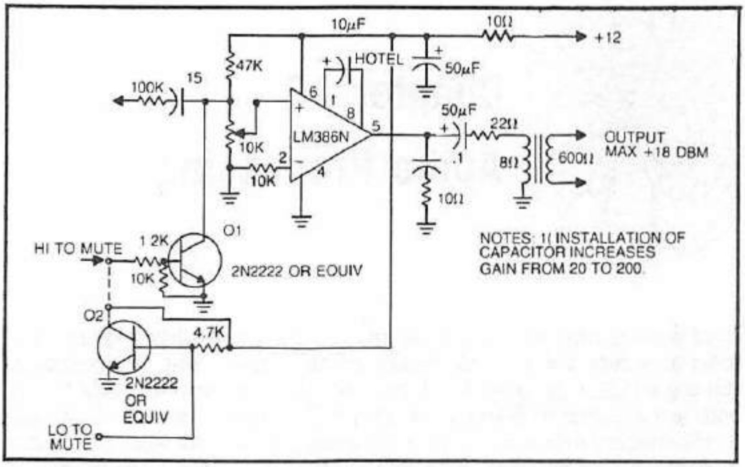
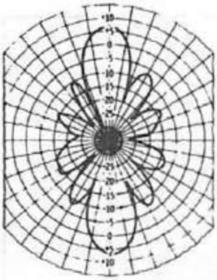


Fig. 18-5. The WA9EXP circuit for a simple audio amplifier that can be used with either a repeater or remote base.

circuit, and provides a maximum output of plus 18dBm to any 600-ohm load. An interesting feature of this amplifier is its built in muting, which can be triggered from the system's logic, or from receiver-squelch action after proper interfacing. If the mute-control voltage is one which hoes high, then only Q1 need be included for your particular use. Q2 serves as an inverter for use with control voltages that go low. This amplifier has many uses other than to recover line loss. Even in a single-site system, it can provide an excellent interface between recovered audio and transmitter input. It is a wide-range device with many uses in the audio portion of your system.



Chapter 19

Audio Processing

Ever wonder why one repeater seems to sound louder than another? Ask most amateurs and you will usually get the answer that one system is running a higher deviation level than the other. When you tell them that both are adjusted to 5-kHz peak, they will sit there with a look of total bewilderment on their faces. They are usually unaware of what is done in a modern amateur repeater, and very few know about "audio processing."

The basic objective of audio processing is to increase the overall modulation percentage without enlarging bandwidth. Since ± 5 kHz has become the national standard for 2-meter FM repeaters, let's work with this standard and see what can be accomplished in increasing overall modulation percentage.

FREQUENCY MODULATION

First, let's discuss the FM modulation process itself. The concept of FM is to maintain a constant carrier level and superimpose the modulation by moving this carrier above and below its operating frequency, doing so at an audio rate. The resultant is a frequency-modulated carrier of constant amplitude from which intelligence can be reproduced by detecting the carrier-frequency variations, amplifying them, and sending them to some form of electro-mechanical or electronic sound reproducer.

There is one flaw in all this, and that comes in the form of the human voice. If the human voice were constant in both frequency and amplitude—that is, if all human beings spoke at a constant level (amplitude), and with constant pitch (frequency), our job would be quite simple. Also, the world would be very dull and boring. The fact is that no two humans have exactly the same vocal characteristics. A rather exacting form of scientific investigation and identification has grown up around this fact—a science called voice-printing. In our discussion we must only concern ourselves with two parameters: amplitude and frequency.

Most communications experts agree that 300 to 3000 Hz is the audio spectrum that will give the best results when electromechanically reproduced, as through a loudspeaker. Simply said, the frequencies above 3 kHz do little to help in establishing high quality communications. Therefore, a rule of thumb is to eliminate the higher frequencies at a pre-established rate known as rolloff. Rolloff is the term applied to the amount of attenuation-per-octave used to accomplish the goal. In commercial service, a nominal figure of from 15 to 18 dB per octave is common. In the majority of imported Amateur FM radios, the rolloff is anywhere from 6 to 12dB per octave.

What about the frequencies below 300 Hz? It is easy to rid ourselves of frequencies we do not want if there is no other frequency above them that we still need. We don't need the audio spectrum above 3 kHz and, as just described, we simply attenuate them into theoretical oblivion. We cannot do the same with 0 to 300 Hz, but we can design audio ciruitry that will tend to pay little attention to them and emphasize those from 300 Hz up to the 3-kHz point where rolloff begins. In practice, this is the approach taken, and we come up with a nominal audio bandpass of 300 to 3,000 Hz.

Let us now assume that we have the audio passband that we desire. Our next consideration is amplitude, or modulation level. In the average amateur transceiver, the overall gain is preset in design to some nominal level to provide enough audio voltage to operate the modulator stage. The only adjustment usually incorporated is a deviation potentiometer, whose purpose is to control the overall frequency excursion of the modulated carrier. In our case, it is adjusted to provide ± 5-kHz peak deviation.

Notice that we have been talking in terms of "peak" deviation, which means the maximum allowable deviation to permit normal adjacent-channel repeater operation—the good neighbor policy. However, we do not really listen to "peak" deviation. This is but an instantaneous condition that occurs during the overall deviation process. Far more important is "nominal" or "average" deviation and, in the case of ± 5-kHz peaks, one's average-deviation level can vary from virtually nothing up to approximately 70 percent of the peak value. These are approximate values derived from knowledge of normal human voice characteristics. However, most people agree that "average" deviation in this day and age is a factor of about .7 of peak value.

Many of us, and many of our radios fail to meet this exacting criteria. This can be heard on any of our amateur bands where the FM mode is in use. Very few stations sound alike, especially in regard to recovered amplitude, that is, a station's apparent loudness to the listener. The same holds true of many repeaters. It happens that there are two schools of thought in relation to the way a repeater should handle the audio recovered from the system's receiver. One group feels strongly that the overall audio characteristic must remain unchanged—that whatever the system hears be relayed as is. The other school feels that any method that will enhance the readibility of the repeated signal should be implemented. This enhancement takes on the name of "Audio Processing."

The most basic form of audio processing is found in just about every form of communications FM transmitter ever designed and built. It is the "peak clipper," a circuit designed to limit the maximum frequency vs amplitude excursions of the modulation process. The peak clipper does just what its name implies: it clips the audio at a predetermined level so as to provide both a more uniform overall modulation characteristic and—to a lesser degree—boost the overall percentage of modulation. However, the clipping process is not a "clean" enhancement technique in that the clipping action produces unwanted harmonics which must be carefully filtered. Because the peaks have literally been "squared off," proper waveshaping techniques are required after the clipper/filter to restore quality to the audio.

While this is applicable to all FM transmitters, it is not exactly what we are looking for in repeater operation. We are looking for a way of dramati-

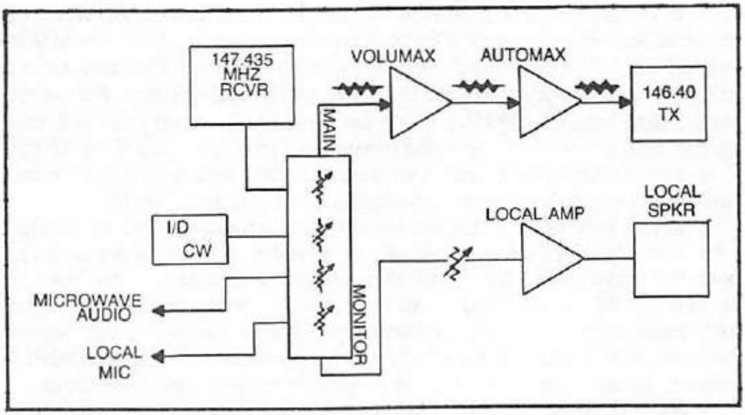


Fig. 19-1. Simplified block diagram of the WR6ABE audio system.

cally boosting the overall modulation effectiveness to some predetermined level. We are also looking for a device that can reduce the level of signals with too much audio. In essence, we are looking for some electronic device that will do to audio what AVC does when applied to RF and IF stages of a receiver. Do such devices exist? Let's look at one system that uses such techniques—the WA6TDD/WR6ABE/WR6AMD/WA6KOS 2-meter repeater located atop Mt. Wilson. For this discussion, we will refer to the system by the best known of its many historic callsigns, WR6ABE.

DIFFERENT TECHNIQUES

Refer to the simplified block diagram of the WR6ABE audio system, Fig. 19-1. Detected audio from the receiver is fed to a mixing panel where audio from several other sources join it. The level of each source can be independently controlled. The output of the mixer feeds both a local monitor amplifier and speaker, while the main output is coupled to the input of a CBS Labs Volumax audio-compander unit. The Volumax is the heart of the audio processing network and functions in a manner similar to automatic-level-control in home tape recorders. A preset value is determined by the system owner, and the Volumax automatically adjusts the average audio to that level. To preclude a "pumping sound" in the audio, the AGC recovery factor is set to respond somewhat slowly: approximately 0.9 second. In the case of WR6ABE, the attack/recovery time is adjustable, though once set, it only gets readjusted during routine maintenance. From the Volumax, the now processed audio is fed to the transmitter through yet another device known as an Automax—also a CBS Labs unit. The simplest explanation of the Automax is that it functions an "absolute maximum limiter" to preclude any chance of audio peaks exceeding the desired level. True, this all sounds very complex, however the results are worth the effort. WR6ABE is probably the "loudest sounding," easiest-to-copy FM repeater in the nation, yet its deviation peaks never exceed 5 kHz. Another system I operate on—the WA6VQP/R repeater on 220 MHz, uses similar techniques with equipment developed and built by Jim Hendershot, WA6VQP. See Fig. 19-2.

Not everyone can obtain equipment such as the CBS Labs Volumax and Automax series of audio processors. However, this does not mean that we must go without. There are today a number of "compander" units sold on the Amateur marketplace, designed primarily to enhance high-frequency SSB operation. Most, though not all, of these units function in a manner similar to that of the Automax. However, the overall requirements of compression and expansion, as well as the time constant, are totally different for FM relay service, and these units will require some modification, or at minimum, a total readjustment. A recovery time of about 0.8 to 1 second and a maximum compression and expansion range of no more than 6dB work out about right. Finally, only units that sample audio are applicable to our use. Units that sample instantaneous RF, and derive their control voltages from this source are not applicable to FM repeater use, and should be avoided.

Another use for audio processing is for relay-system control. See Fig. 19-3. One of the problems faced when trying to remote control a repeater is falsing. The problem arises out of the fact that our voices contain the same tones that activate our circuits. Many systems use the 567 type of PLL tone-decoder to sense control tones, and, as anyone who has tried will attest, this is not always easy to do. There have been cases of systems scrapping 567-based control decoders because of an endless problem with continual falsing.

As it turns out, the 567 can be used reliably, but you must know its secret first. If overdriven, the 567 will perform poorly. If a proper audio level of 200 mV or less is maintained on the input, it will be quite reliable and exhibit a minimum of falsing. The circuit shown in Fig. 19-4 will do the job.

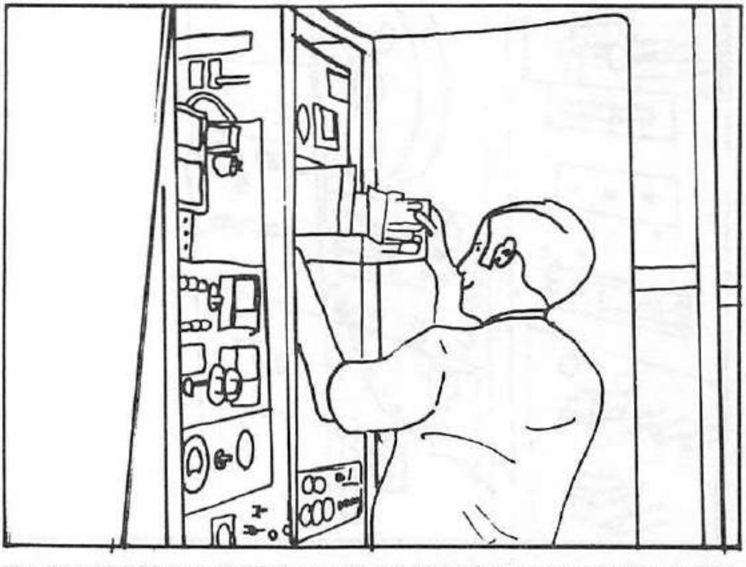


Fig. 19-2. Burt Weiner, K6OQK, servicing his WR6ABE repeater. Burt pioneered in the use of audio processing in amateur repeater service.

This is a circuit designed by Warren Andreasen, N6WA, first published in the S.C.R.A. Spring 1977 Newsletter, and was field proven in over 300 paging decoders prior to that.

The circuit will take audio at almost any level, and amplify it to any preset level. The type 741 operational amplifier (Op-Amp) provides the gain, and when the rectified, sampled, output-audio reaches the proper level, it causes the MPF-111 drive-control transistor to adjust the gain of the 741 so as not to permit any increase of output. Within reason, regardless of the input, the output level will remain constant, preset. By adjusting the output-level potentiometer to put the proper audio drive on the 567 decoders, you will have a controller that will have minimal falsing in normal operation.

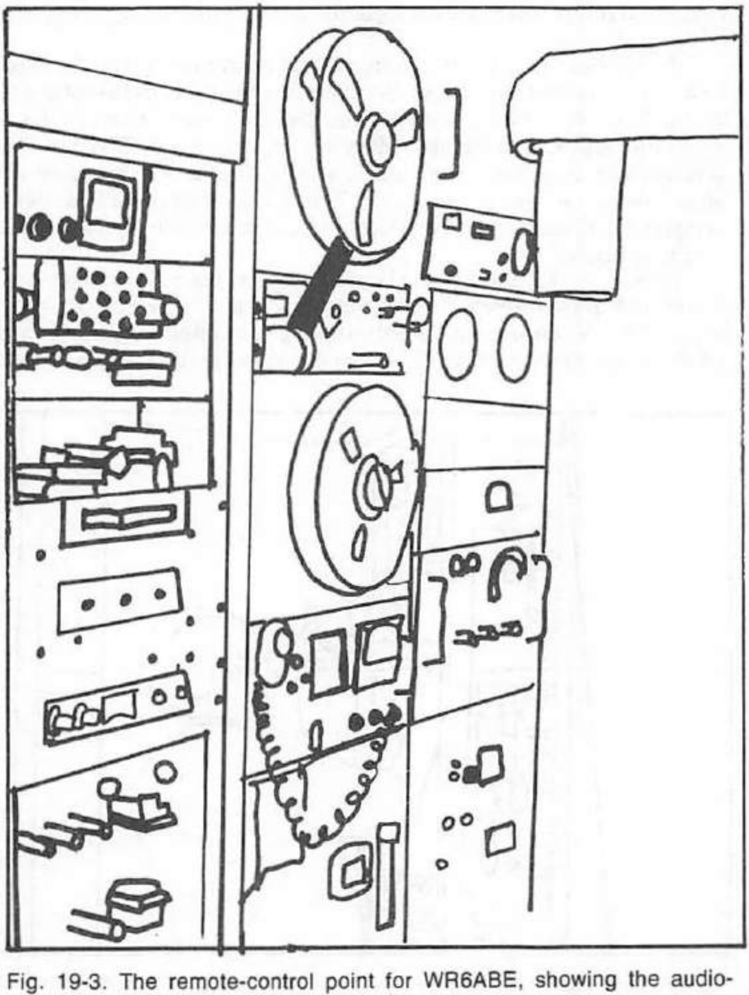


Fig. 19-3. The remote-control point for WR6ABE, showing the audio-processing, voice ID, and logging recorder systems.

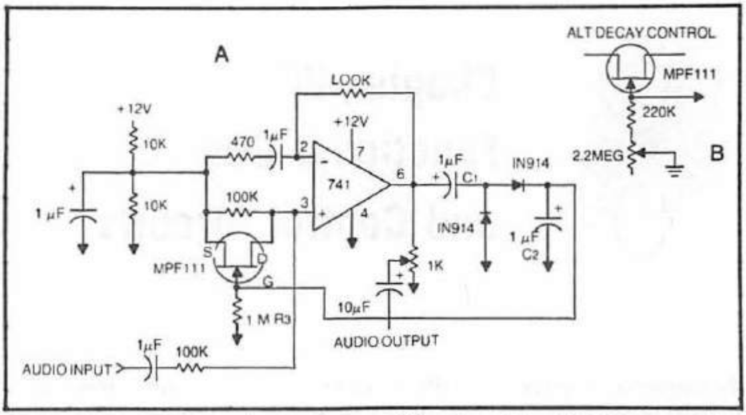
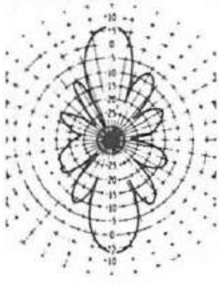


Fig. 19-4. The N6WA audio-levelling amplifier, A, and the WA6VQP variable-decay-time modification, B.

This circuit does great things for any control decoder, and is not limited to the type 567 decoder chips. In fact, as other amateurs using it have found out, it need not be limited to leveling control tones, but can act as a good all-around audio AGC amplifier. Its recovery time can be adjusted by changing the size of C1 and C2. The larger their value, the slower both the attack and recovery time. The 1µF value shown is excellent for tone-control applications, however, the values may have to be increased for voice operation, and some experimenting may be necessary. The input impedance is in the neighborhood of 100 kilohms, making it a circuit that can be used just about anywhere.

Another possible modification to this circuit, especially advantageous in its use as an overall audio-level-control amplifier, is to provide variable decay time. This can be done by replacing R3, a fixed 1-megohm resistor, with a combination of a fixed 220-K ohm fixed resistor and a 2.2 megohm potentiometer. The values of C1 and C2 are left unchanged. This combination of R and C gives a rapid attack time and a decay time of the operator's own choosing which can be adjusted to suit the needs of the individual system. For convenience, the 2.2-megohm potentiometer can be remotely mounted on the system's control panel. However, shielded leads must be used to connect it to the amplifier board, and the wiper ground must be connected to the amplifiers ground buss to avoid hum or other forms of unwanted audio interference.

Audio processing in amateur repeaters has come of age, and, in this day and age of narrow deviation dictated by close channel spacing, there is still no reason for a system's audio to sound thin and hard to understand. While units like the Volumax and Automax are nice, they are rare and extremely expensive. Similar units are manufactured by RCA, Altec, and others, but they are well out of the price range of most Amateurs. However, with only a bit of ingenuity, Amateur equipment can be either modified or built to serve in similar applications. Thus, even though you may be limited to ± 5-kHz peak deviation on 2 meters, you can have a system that sounds "loud" and is easy to copy.



Chapter 20
Functional COR and Control Circuits

The carrier operated relay (COR), which may or may not have a relay, is a vital part of any AM or FM repeater/or remote base. Actually more than a mere relay, the COR is a "squelch-responding" circuit that provides a relay closure with each signal that occupies the channel. This contact closure is then processed by logic circuitry, be it relays, TTL, CMOS, or microprocessor, and then used to key the push-to-talk circuit of the remote transmitter so that the "repeat" operation is fully automated.

Since nearly every type of repeater application is functionally dependent on the presence or absence of carriers, the COR can be used in a variety of ways to perform a number of on-off functions. In fact, the absence-of-carrier is as often used as is the presence-of-carrier state.

PRINCIPLE OF OPERATION

The principle of operation of a typical COR is actually quite simple: When no carrier is present, noise would ordinarily appear at the speaker. A good FM receiver couples the higher-frequency components of this noise to a noise amplifier, the output of which is rectified and fed to a squelch amplifier which keeps the audio amplifier in a cutoff state as long as the noise is present. But when the noise disappears, indicating the presence of a carrier on the frequency, the audio amplifier comes on.

A standard DC amplifier can be driven with the same signal that is supplied to the squelch amplifier, and thus we can obtain a "signal" to feed to our repeater logic. This signal might be a relay closure, a transistor saturating, a TTL or CMOS level, change or whatever we desire.

A TUBE-TYPE COR

Figure 20-1 shows a well-designed COR which uses a 5963 tube as the control element. Variations of this circuit have been widely used in a great many tube-type, commercially produced units in the past. It should be noted, however, that this circuit is not applicable to all squelch types. It is ideal for use in most Motorola and GE receivers, for example, but cannot be used on many RCA and DuMont units without modification.

The principal requirement of the receiver is that a no-signal condition must be indicated by a positive signal at the grid of the squelch amplifier. (The signal at this point is not really critical, and can be at "zero" potential or even slightly on the negative side.) When a carrier appears on the input

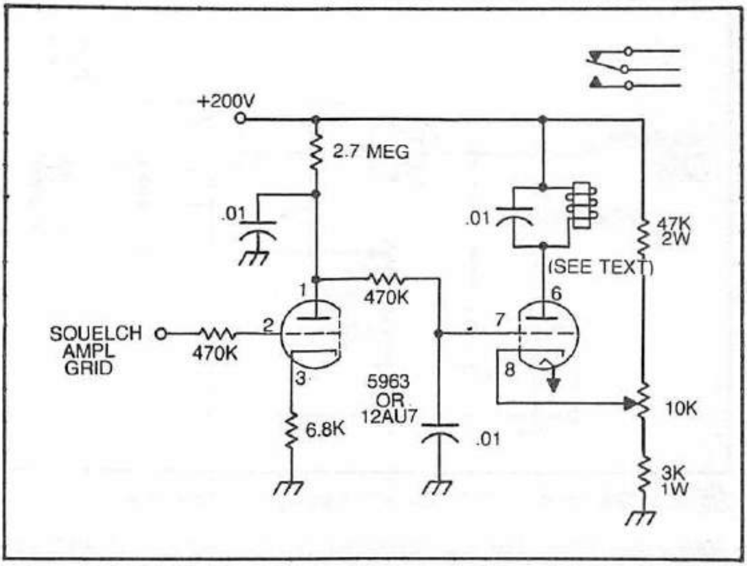


Fig. 20-1. Universal Carrier Operated Relay (COR).

channel, the polarity of the voltage on the squelch-amplifier grid must swing to a definite negative value. If the idle no-signal voltage on the squelch-amplifier grid is significantly negative, some means of compensation must be employed in order to use the illustrated COR circuit.

A TRANSISTORIZED COR

The mechanical relay of most vacuum-tube COR circuits is a standard current-activated plate relay with a coil resistance of 8 to 10K ohms. A delicate device, it should never be used for any function other than driving a heavier relay with multiple contacts (with normally open and normally closed capability). If this rule is strictly adhered to, the COR's service life will be lengthened and its operational reliability enhanced. The 5963 tube in the circuit has the same pin layout as the popular 12AU7, 12AT7 and 12AX7, any of which are usable in the circuit. The 5963 is more adaptable to COR applications, however, because it was designed for use in old-style computers and is constructed with a built-in capability for being held in a state of cutoff for extended periods.

Figure 20-2 shows a two-transistor COR which uses a conventional 28-volt dc relay rather than a current-actuated plate relay. The circuit, designed by Jerry Schneider of Los Angeles, California for incorporation into his uhf mobile telephone repeater, can only be used with vacuum-tube receivers such as the GE and Motorola units for which the circuit in Fig. 20-1 was designed. Although the basic operating principles are the same for both tube-type and transistor receivers, the pictured circuit must be modified for adaptation to a solid-state squelch amplifier.

There are no critical components in the solid-state COR. The transistors can be any NPN type capable of switching at a collector current of

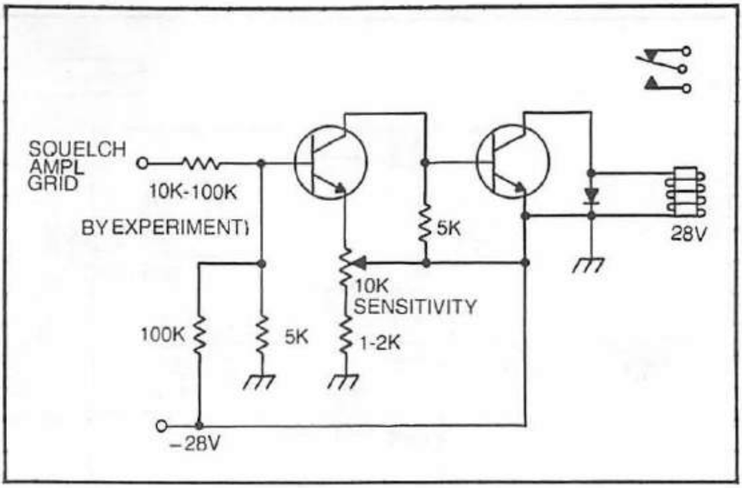


Fig. 20-2. Solid-State COR for use with tube-type FM receivers.

greater than 50 mA. The only criterion for the relay itself is the ability to pull in with a voltage lower than the supply voltage.

The low impedances and critical polarity requirements of transistors impose certain constraints on squelch and COR design. Unfortunately, the COR designed for compatibility with one transistor squelch circuit may not be compatible with another. Many transistor squelches do have one characteristic in common, however: they exhibit a very small voltage change from the signal to the no-signal state. The voltage swing might be as small as 1.0 volt; the squelch amplifier on the Motorola DCN series handheld units, for example, has a no-signal potential of approximately +0.5 volt. An incoming signal causes the voltage to swing to a negative value of − 0.7 volt. Such small signal changes cannot be used with conventional COR circuits, but

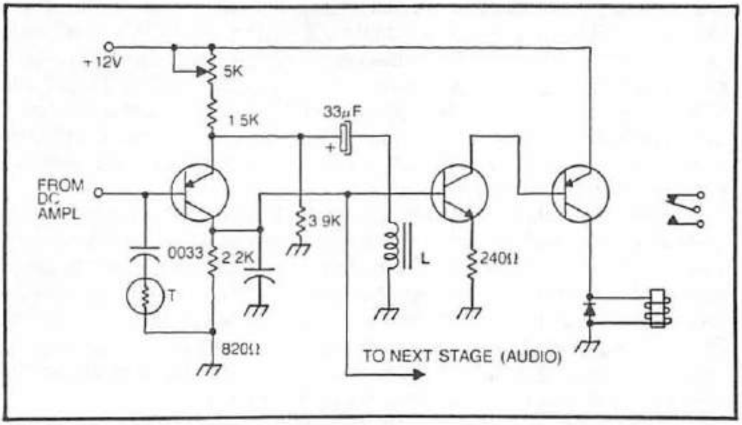


Fig. 20-3. GE MASTR COR circuit.

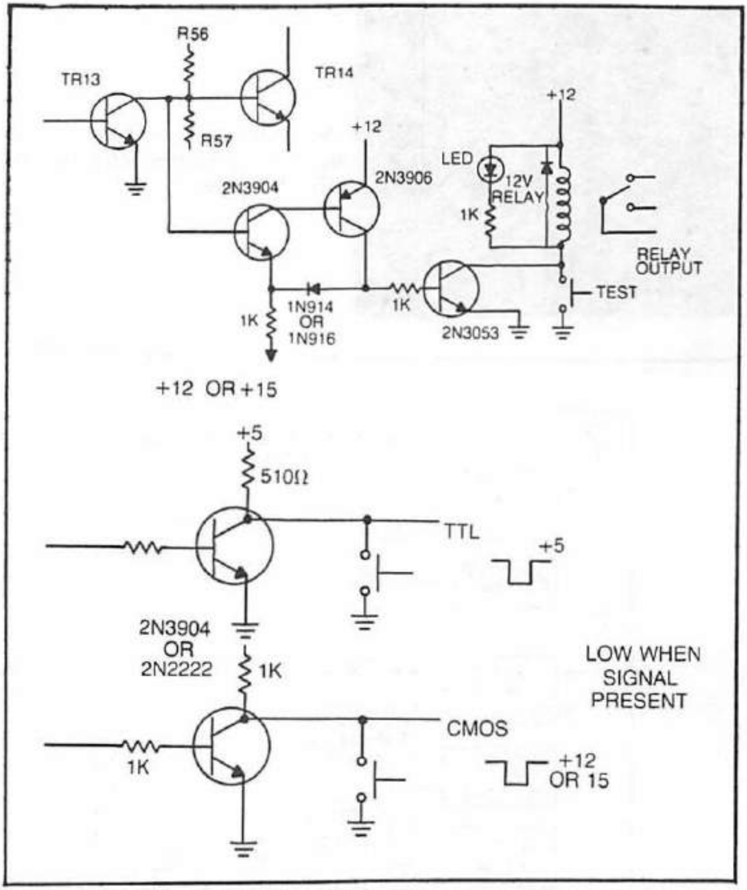


Fig. 20-4. A COR for Clegg FM-76 rigs, with TTL, CMOS, or relay output.

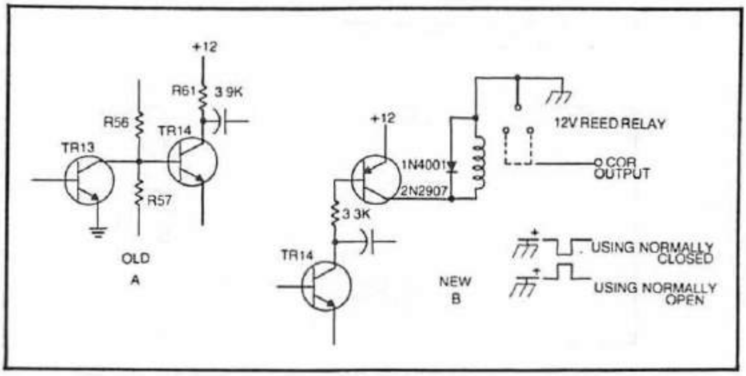


Fig. 20-5. COR circuit that can be adapted to a Clegg FM-76 transceiver.

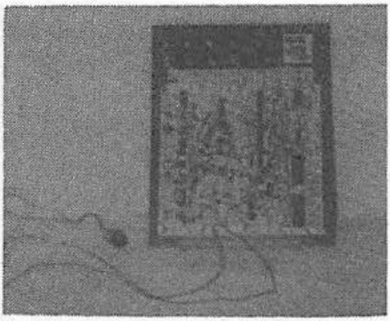


Fig. 20-6. The Porta-Peter controller. The cable plugs into a Midland 220-MHz receiver.

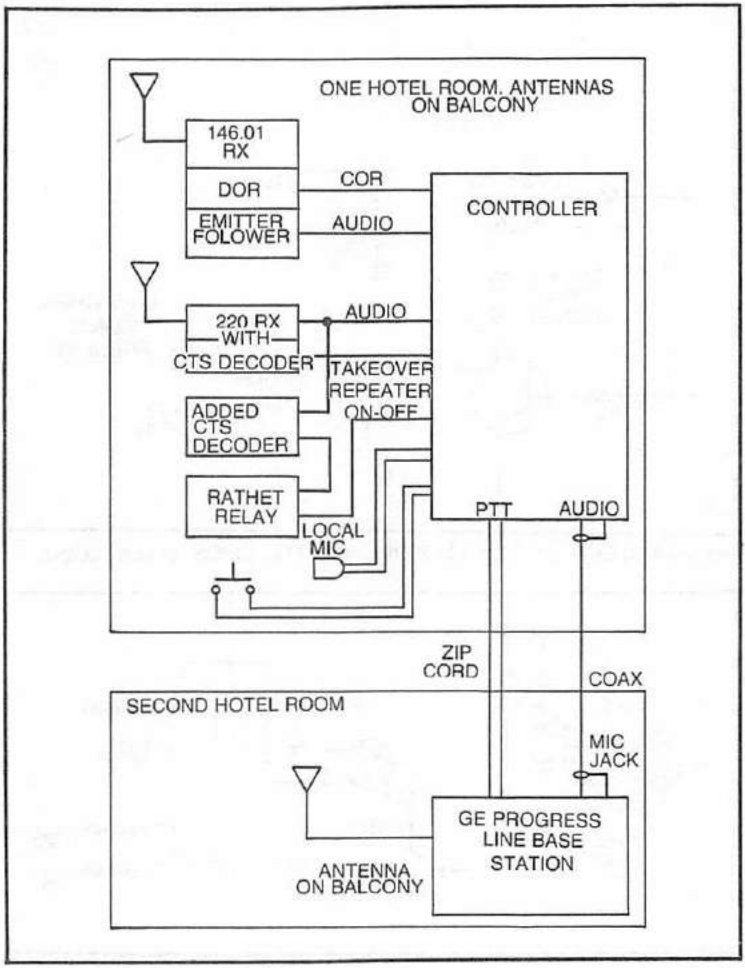


Fig. 20-7. Block diagram of the Porta-Peter.

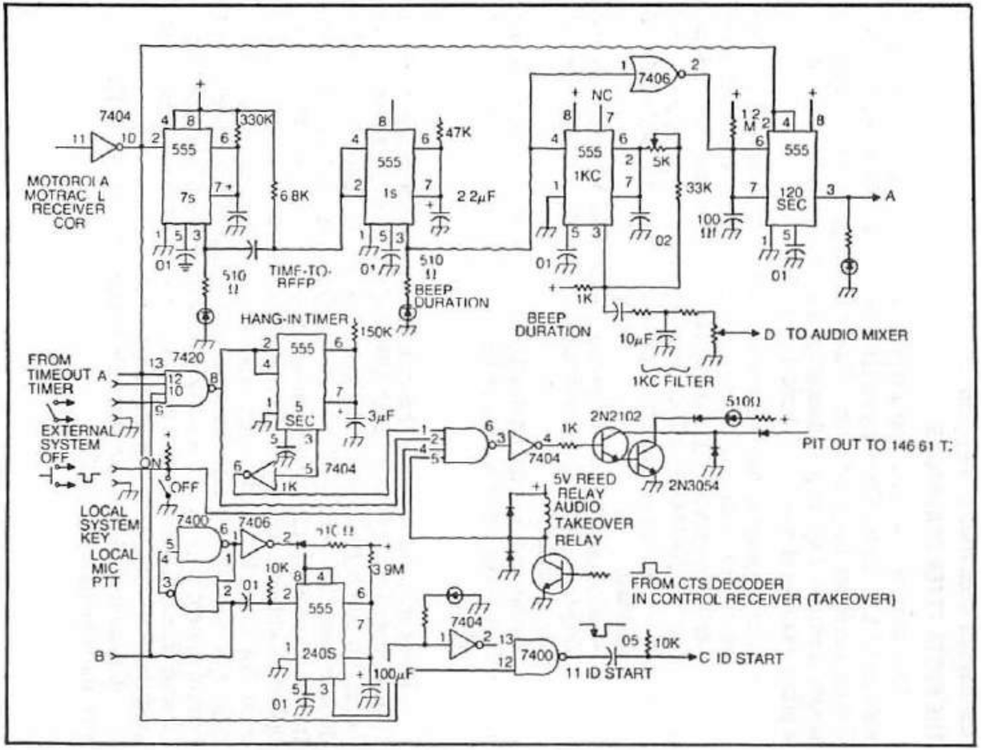


Fig. 20-8. Schematic diagram of the Porta-Peter control.

they are quite compatible with low-signal devices such as Schmitt triggers, which can themselves be used for relay control.

Figure 20-3 shows a solid-state COR circuit such as the type employed by GE in its MASTR series of two-way units. Presence of a signal on the receiver channel of interest causes a sharp increase in the negative squelch-amplifier output voltage. This distinct rise in negative voltage can be used as a bias source to hold a transistor or diode gate open for COR control.

The circuit in Fig. 20-4 was designed by N6WA for use in his 220 MHz repeater, and has the unique option of relay output, TTL or CMOS output, depending upon what output stage is chosen. The components with parts identifier, i.e. R56 or TR14, are existing parts in the Clegg FM-76.

Another good COR circuit adaptable to the FM-76, suggested by a friend, is shown in Fig. 20-5. It has been tried on a Proto-board, and works, but has not been tried in a system.

THE PORTA-PETER CONTROLLER

This controller was built on a type 104 *Proto-Board** between midnight and 3 A.M. on the Thursday morning before the 1978 ARRL National Convention in San Diego, after one of those late-night coffee klatches that always seem to last too long. A photograph is shown in Fig. 20-6. This unit is a prime example of how not to build a controller:

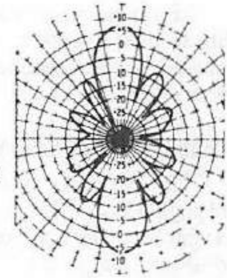
- 555s are used as tone generators. Yes, they do have filters, but what if one of the capacitors opened? The only reason that they were allowed was that, (a) this 146.01/.61 repeater was a 3-day unit, (b) the 146.625/025 repeater was over 125 miles away, and (c) the convention hotel was in a valley, which provided additional shielding.
- Nothing, except the audio levels, is adjustable. As a minimum, the hang-in and timeout timers should be adjustable, but again, this unit was a quickie.
- A schematic was drawn (finally) 2 months after the convention.
- Don't ever try to design or build something when you are half asleep.

There are plans to rebuild this unit, and some of the changes will be: (1) use either Intersil 8038 or Exar 2206 audio oscillators; (2) use CMOS Logic; (3) add better control methods. The system used was 2 CTS decoders on a 220 MHz Midland receiver. One controlled a rachet relay (pulse on-pulse off) for repeater on-off, and the other gave the control operators audio override; (4) Get rid of the noisy relays. Reed units, I don't mind, but the click...clatch...click...clatch all night kept me awake as the night owls kept the repeater busy. The Motorola Motrac receiver and control system were in author's room, with W6SPK's GE Progress-line, 30-watt transmitter in a room 2 floors above, connected by a piece of zip cord (for PTT) and a piece of RG-58 coax (for audio).

A system/block diagram of the *Proto-Board*™ is shown in Fig. 20-7 with the schematic in Fig. 20-8.

Chapter 21

Letting the World Know You're There



Part 97:84 of the FCC Rules and Regulations states that all Amateur stations shall identify a minimum of one time during any 10-minute transmission period. This is true for repeaters as well as our individual stations. In the case of repeaters and other relay devices, this regularly scheduled ID can take the form of modulated radiotelegraphy or telephony. In this chapter, you will be shown a number of circuit designs that will help you comply with this regulation. However, let us first look at what each system has to offer.

ID SYSTEMS

MCW ID

Modulated CW normally abbreviated MCW, can be anything from a simple, punched tape actuating a microswitch which in turn operates an audio oscillator, up to a similar oscillator keyed from the output of a microprocessor system. Over the years, many designs have come and gone. All have had but one objective—generating the necessary CW characters to properly identify a station.

Voice ID

Though still in the minority in comparison to the number of MCW IDs in use today, the voice ID is very popular with many system operators; either alone or in combination with an MCW ID. Most voice IDs are generated from tapes recorded and automatically re-played over one's system. Though many tape formats can be used for this kind of operation, by far the most popular is the broadcast spot-announcement tape-cartridge machine. While it's true that home-entertainment type cassette and 8-track players can be made to function in this service, both have certain drawbacks. First, most home-entertainment devices were never designed for this type of service and will not exhibit the necessary long-term reliability needed in remote relay service. Secondly, most home machines have no form of exact reset cueing which is necessary so that the message can be activated, sent, and reset to the exact starting point for replay. Broadcast "Cart" machines, on the other hand, have audio cueing as a built-in feature since, in many cases, they are operated remotely or in automated sequencing. It is no wonder then, that in Amateur repeaters using voice ID, names like Spotmaster and McKenzie are common.

Proponents of "Voice ID" claim that it lends both class and individuallity to their systems. Opponents claim that the voice ID interferes with overall communication and interupts the train of thought. The final choice is yours to make as you tailor your system to your needs.

Cautions When Using Voice ID's

It's very easy to "overdo" a voice ID without even trying. The purpose of any ID system is to comply with the FCC Regulations. As such, the ID is a very secondary part of the system, and should always be thought of in that position. This is not to say that one cannot be creative, but, at the same time he should remember that in normal day-to-day operation, the same people will be hearing it very often. It's easy for something "super cute" to become "old" very fast.

Creativity takes forethought. Perhaps the best known of all voice IDs ever aired began on the WA2KEC repeater back in the early 1970s when a number of well-known CBS-TV News correspondents became the ID voice of the WA2KEC (now WR2ACD) repeater. What made this voice ID "class" was the overall simplicity of it. The text was simple, yet everyone knew the voices they were easily recognizable. Similarly, the Disaster Amateur Radio Network in Los Angeles operates a number of Los Angeles intertied repeaters with another well-known voice; that of Actor-Comedian Dick Van Dyke. Hearing Dick Van Dyke's voice issue forth with: "From high atop Verdugo Peak, this is WR6.... " or "Looking down from 5000 feet above Los Angeles, this is WR6...." adds a very special "something" to the overall DARN operation.

However, you need not go forth to solicit a world-famous newscaster or entertainer to have a truly successful voice ID. Both the WA2KEC and DARN IDs are the exception rather than the rule. The important thing is that the voice or voices used be pleasant sounding and easily understood at an audio level below that of normal user conversation. Simply, a good speaker that you yourself will not mind hearing over and over again.

Once you have decided upon your announcer, it is important to know how to properly record such an ID. If you are dealing with a professional announcer, entertainer, or newscaster, there's no real problem. These people are attuned to doing such work, and you need only let them know what you want and it will be done. However, your choice may not be a professional. He/she/they may not know the secret of timing, and it may take many recordings before you obtain something close to what you want the finished product to sound like. Therefore, unless you are dealing with a "pro," never directly record the announcement onto the ID cartridge. Rather, record it on a reel-to reel tape machine at the fastest speed available. Then, decide on a time for your ID, and write a script to fit that time. Normally, you will want to keep the ID under 15 seconds total time, though I have heard many that are longer and a few that were shorter. I personally feel that between 10 and 15 seconds is ideal. Much can be said in such a short time without really hurrying. For example, if I were to use a voice ID on my machine it might say: "Repeating 146.955 MHz, this is WR6BAX Los Angeles." I have satisfied Part 97:84 by including both the system callsign and the fact that it was a repeater, and, in addition, letting all who might hear its output know that they can find its input some 600 KHz

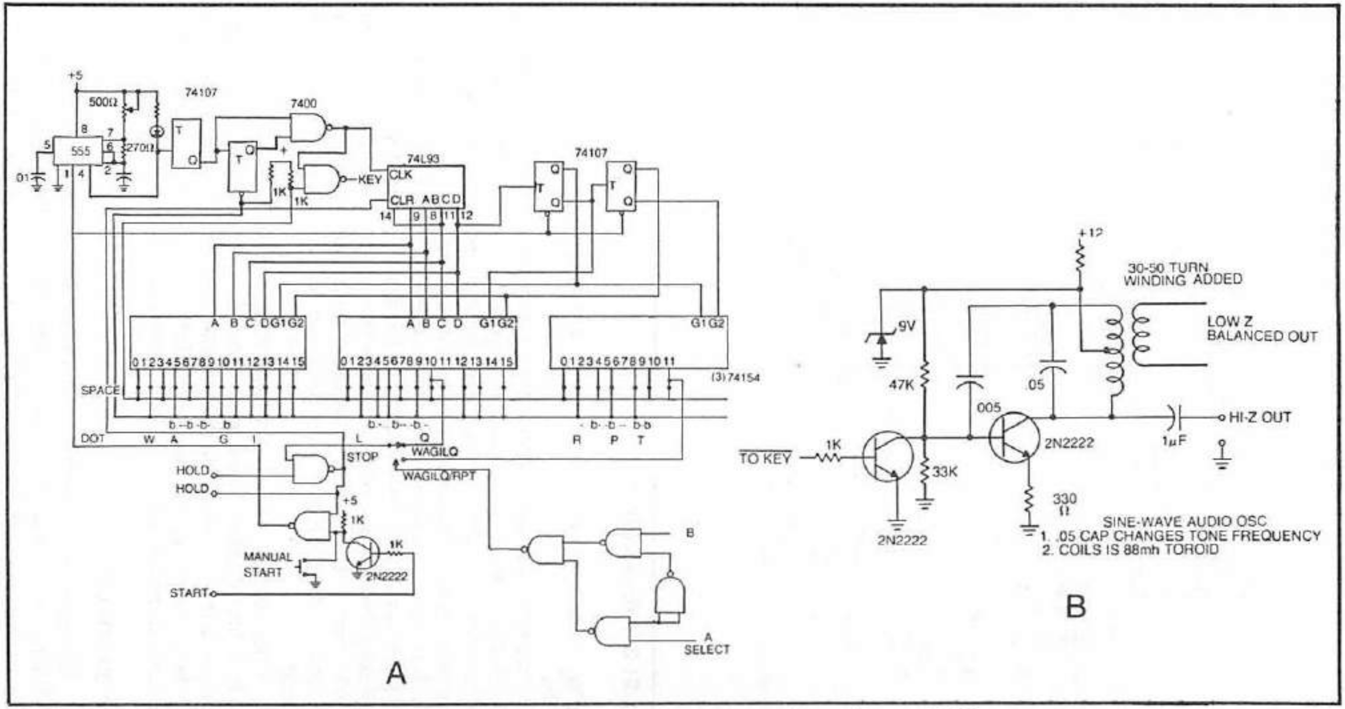


Fig. 21-1. A 48-element IDer with variable stop points at (A), and a sine-wave audio oscillator with ID tone generation at (B).

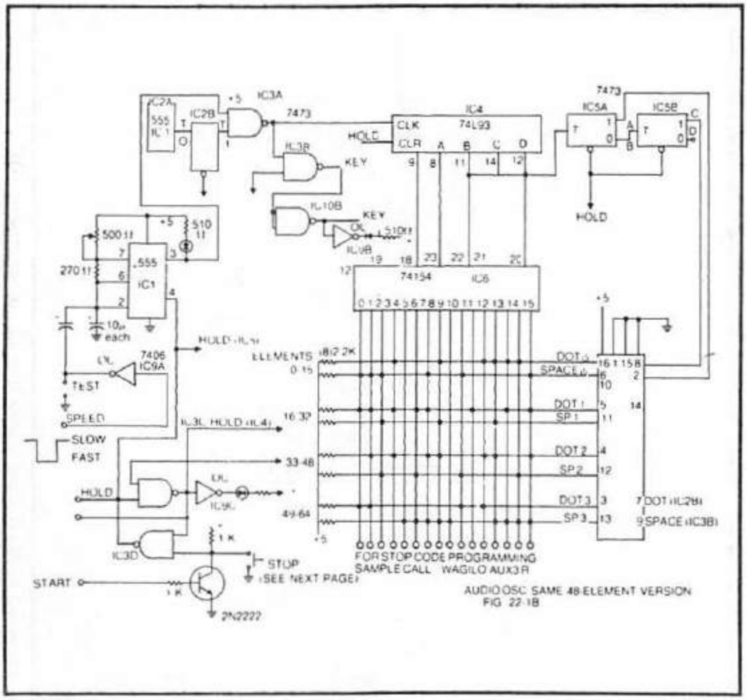


Fig. 21-2. A 68-element IDer.

higher. Simple, effective, informative, and easily stated in under 10 seconds.

Suppose you have written your ID, recorded it many times, and still have not been able to get the kind of sound you want. The inflection is good, but there are too many pauses or a few mistakes made that your announcer cannot seem to get right no matter how many times he tries. All is not lost if you know how to edit tape, or have a friend so adept. While audio-tape editing is not all that easy, it can save the day. You would be surprised at how good a skilled tape editor can make even a mediocre announcer sound. The key here is to edit out the mistakes, or take out the pauses by "knifing" the tape. That's the reason for recording the copy on high-speed, open-reel format.

Once you have exactly what you want, transfer it to the ID cartridge itself. True, you have added another dub-down generation to the ID tape process, but by doing so you have a factor of control that otherwise would not be possible. If you have recorded your master on a high-quality machine, using a quality microphone, there will be little audio degradation.

CW IDENTIFIERS

Identification of repeaters and remote bases is an FCC requirement, and therefore is one thing that every repeater or remote builder is going to have to face sooner or later. Digital IDers have progressed so far that the old techniques of rotating code wheels, punched tape, stepper switches jumpered to generate code, and other mechanical devices are not even considered for new systems any more.

The IDers presented in this chapter are proven designs, in both TTL and CMOS logic. They are not the only good designs around, but are the author's favorites.

Two of the circuits are variations of the Peter Stark, K2OAW, design that first appeared in the February 1973 issue of *73* magazine. In Fig. 21-1, I have replaced the clock circuit with a 555, timer IC, and modified the circuit to include 48 elements, and added variable stop points. A few months later, I was asked to come up with a 64-element design to allow the ID of the links in a multi-site system—for example "WA6ILQ/AUX 3" with option of an "R" at the end of the string. A few hours later, an "extended" K2OAW design was operational. It was essentially the same as the original, except for the 555 clock. The current drain was too much, due primarily to four 74154 ICs.

After going through the TTL data books, the circuit of Fig. 21-2 was developed, and the power drain was cut in half. Conceivably, the circuit could be expanded to 128 elements—that hasn't been tried yet—but the idea is shown in Fig. 21-3.

The next circuit Fig. 21-5, is a 128 element PROM based version of Fig. 21-2. This need arose when Jim Walls, WB6WMW, asked the author to come up with a small unit for wiring into a T/Hunt transmitter. It had to have enough room in it to say "MWRA HIDDEN TX FIND ME WB6MWMW," with easily changed PROM, so that the person who was hiding could plug in his PROM chip with his call.

Since these circuits were designed, low-power and CMOS versions of the 555 have been announced by several manufacturers. In fact, an Intersil ICL 7555 (CMOS version) is playing in one of the author's projects.

All of these circuits use 555 chips as master clocks, and in the CMOS versions, that is the chip that uses most of the power. The substitution of a

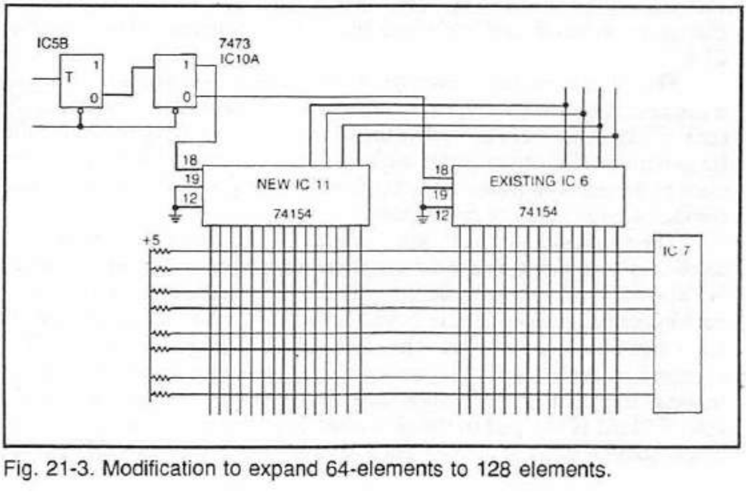


Fig. 21-3. Modification to expand 64-elements to 128 elements.

low-power or CMOS 555 would be the first change suggested if a low-power IDer us needed.

The last circuit was contributed by Ray Thill, WA9EXP, and works on a slightly different principle than K2OAW's design. Where the OAW design uses the position of a single diode to indicate a dit, dah, or space, Ray's uses the diode as a time frame; a single diode for a dit; three for a dah, and none for a blank. While this technique uses more diodes, it has the advantage that it is easier to set up the code. See Fig. 21-4.

WA9EXP CW IDENTIFIER

This device will automatically generate the system call letters at the beginning of a series of transmissions and at three-minute intervals thereafter. If a transmission is less than three minutes in length there will only be one ID at the beginning, and it will not key the transmitter to put an ID on the air—which may interfere with simplex activity. There is a provision for a continuous ID for test purposes as well as an ID inhibit, which may prove useful for autopatch purposes. During the ID cycle, the transmitter PTT is activated to prevent sending a partial ID.

The ID generator is self-contained, except for power, on a 4½ by 6½-inch printed-circuit card with a 22-pin edge connector to match an appropriate socket. Provisions are made for using external power of either + 5 volts DC, or + 7 to + 28 volts DC with an-on-card regulator. The regulator need not have a heat sink (MC7805CP) if a 12-volt source is used. All of the timers, and the audio-tone generator, are on the board. Be sure, on all audio sources except CTSS, to insert the modulation before the modulation limiter and splatter filter. An unlimited, unfiltered squarewave will produce severe spurious signal in adjacent channels.

For almost all call letter combinations, the 127-bit diode "ROM" should prove to be adequate. The unit was built from TTL because of availability, cost, and ease of construction—no static problems. It is a single-sided board with a few jumpers. The diode matrix is wired to a buss wire above the board. The hand-wired matrix is easy to program and change as required, and is cheaper than a programmable ROM, see Fig. 21-6.

The interface to the transmitter is very simple, see Fig. 21-7. All that is required from the receiver is a contact closure to ground. The transmitter PTT line is pulled to ground by the COR via a diode, or the output of the ID generator. The transmitter audio is a direct connection to a suitable place in the audio amplifier of the transmitter—or possibly to the mic input through a large value of resistance.

The main clock for the system, (Fig.21-8), is a 555 timer chip wired as an oscillator, running at approximately 67 Hz, which gives you about 20 WPM—the FCC limit on code generated by automatic devices. This permits operation independent of power lines, and provides a wide range in code speed for test purposes. The clock output is divided by a pair of 7493 counters to drive the 74154, a four-to sixteen-line decoder. This steps through 16 positions in the diode matrix, and when it reaches the end of a row, a 74151 is stepped to the next row. This continues through all eight rows, sixteen steps at a time. There are 127 diode positions. The 74151

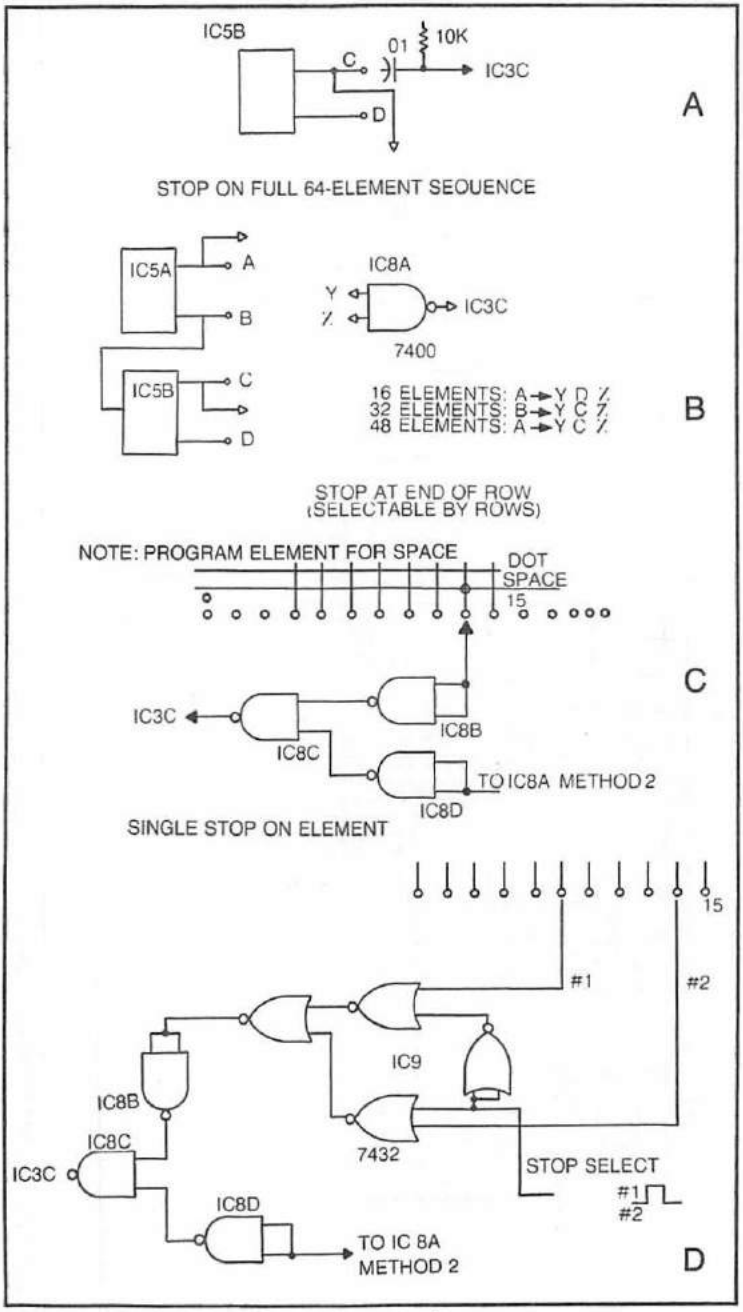


Fig. 21-4. Stop techniques for 64-element unit.

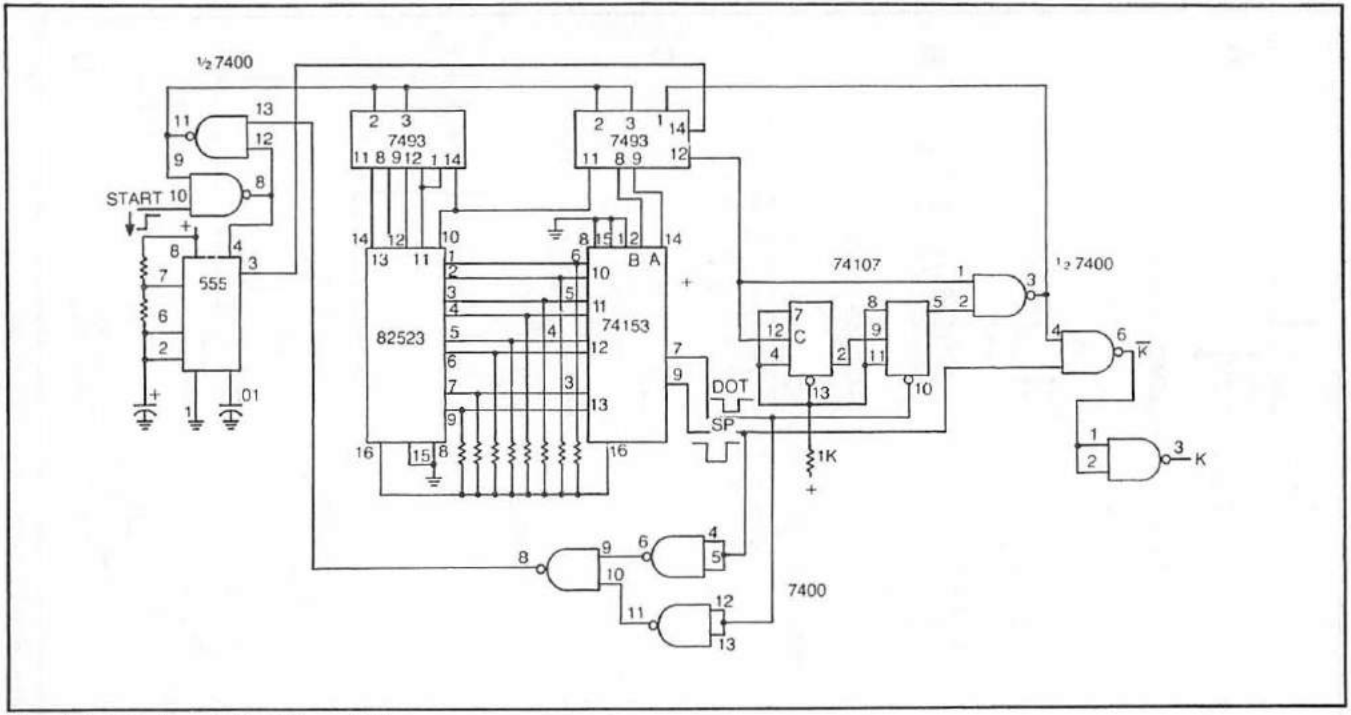


Fig. 21-5. 128-element PROM-based IDer.

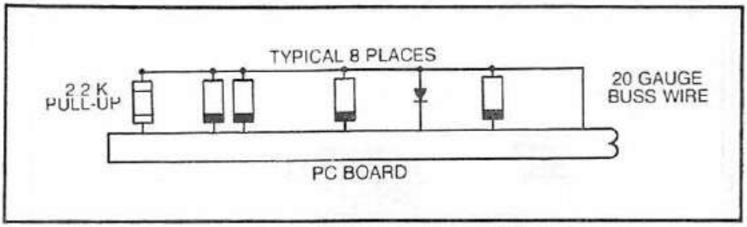


Fig. 21-6. Method of mounting diodes in the matrix of WA9EXP IDer.

takes the selected data, a diode or an open, and transfers this information to the input of a 555, which is wired as an audio oscillator that generates each code element. The output of the 555 is filtered to provide a pleasant tone to modulate the transmitter. The frequency is nominally set to 1066 Hertz, which is the geometric mean frequency of the high end of the low Touch-tone group and the low end of the high Touch-Tone group. The third 555 is wired as a three minute timer for the sequence of generated IDs. A 2N3053 is used as an output for the transmitter PTT line.

Programming

This unit is programmed by installing diodes vertically (cathode band toward the PC board) in positions where a tone is desired. See Figs. 21-9 and 21-10. The first position is blank, as this is where the ID generator is stopped while it is in the standby position. Looking at the component side of the board with the diode matrix in the upper left corner, you read the matrix just like you would read a book, left to right, top to bottom. One diode is installed for a dit, three diodes for a dah, one open for a space and three opens for a space between characters, all open after the end of message. A sample program is shown for WA9EXP/RPT, Table 21-1.

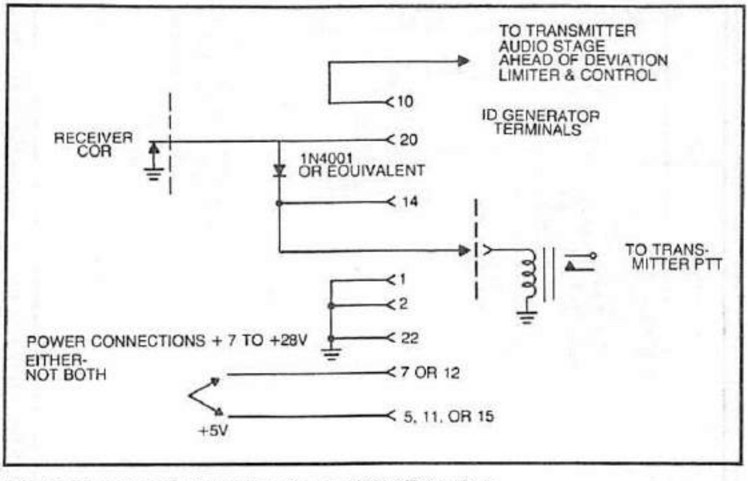


Fig. 21-7. Repeater interface for the WA9EXP IDer.

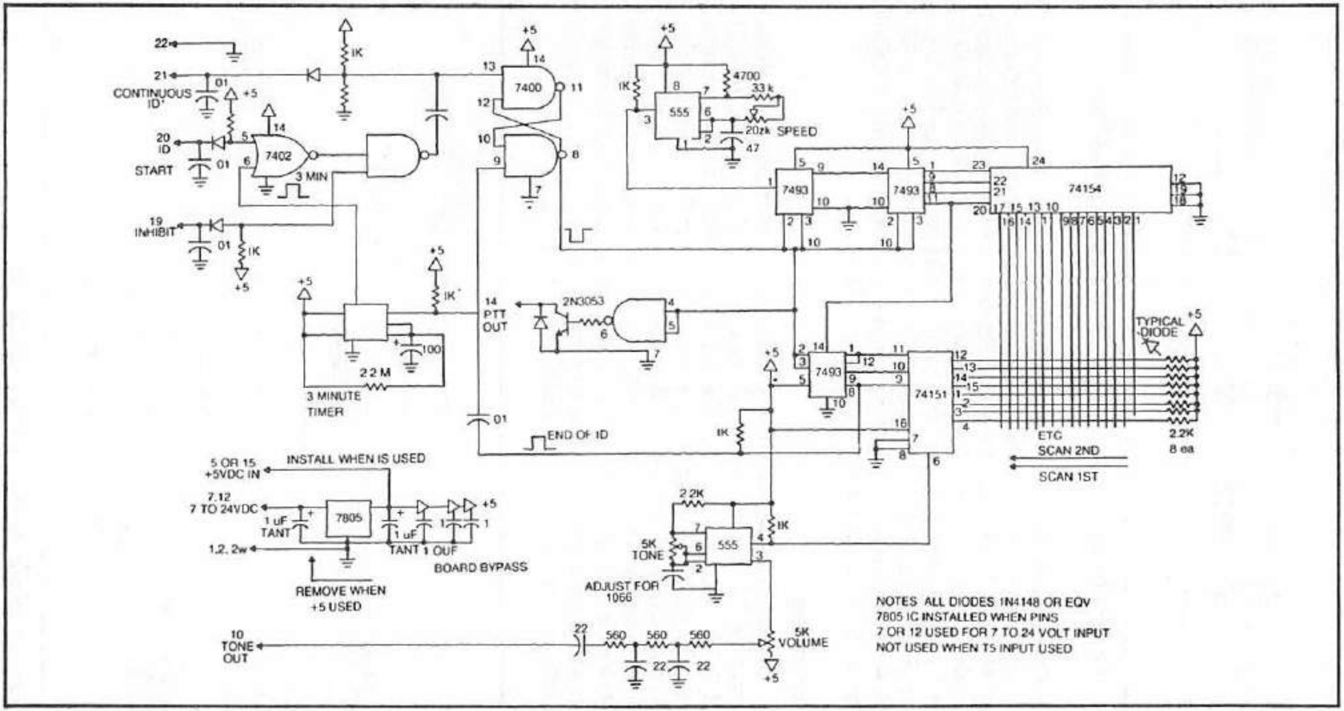


Fig. 21-8. Schematic diagram of the WA9EXP CW identifier.

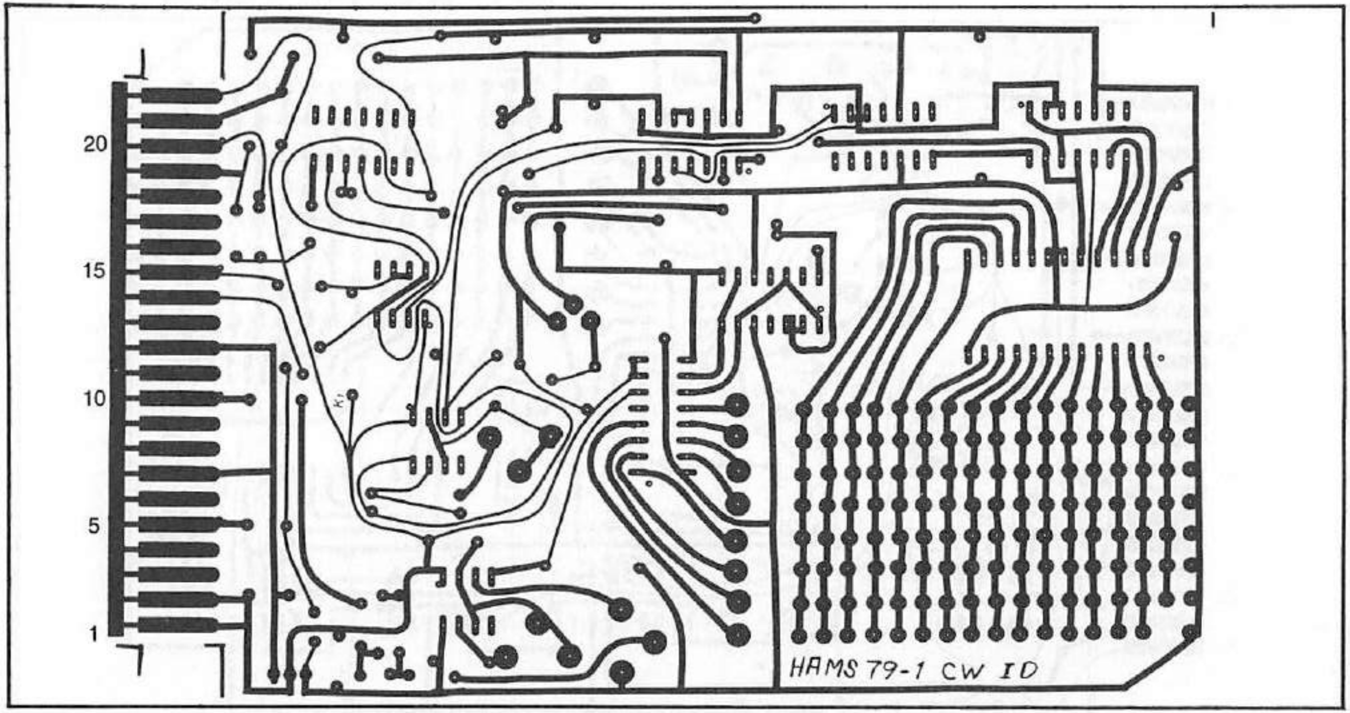


Fig. 21-9. Printed circuit layout of the WA9EXP board.

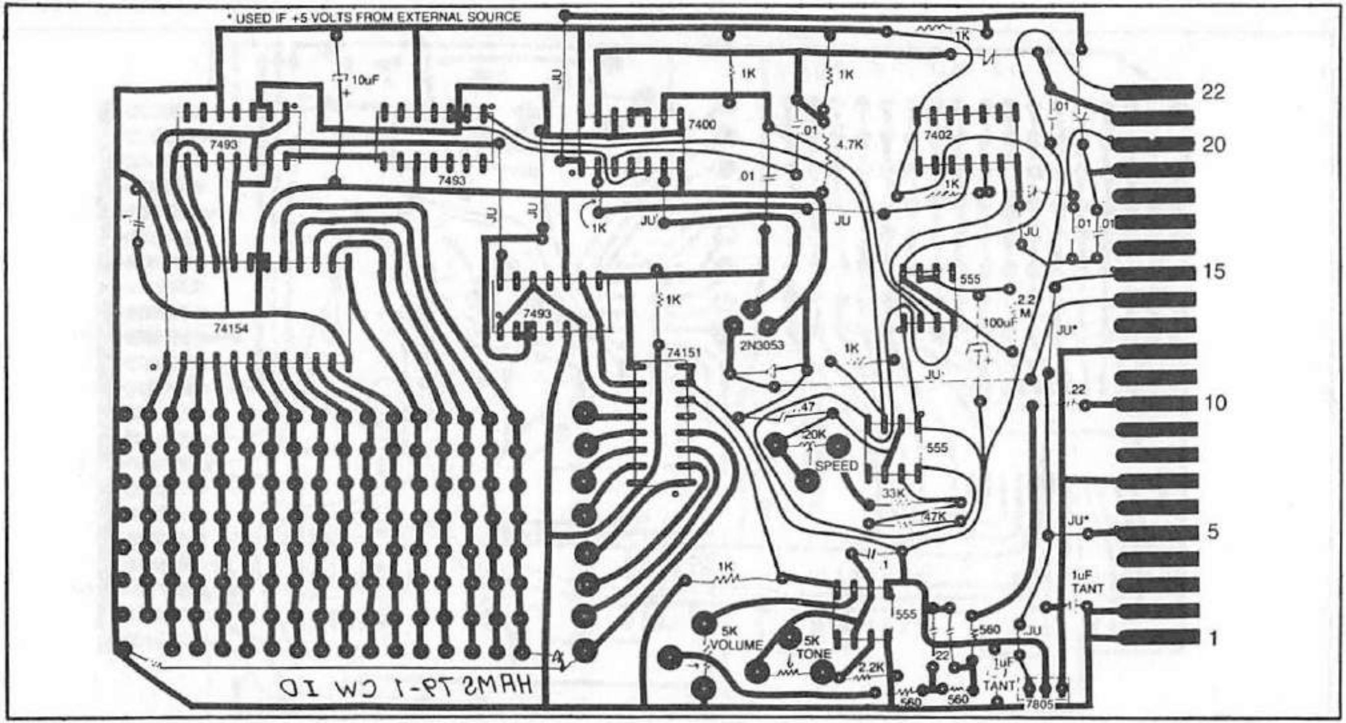


Fig. 21-10. Parts placement guide for the WA9EXP IDer.

USING THE ID FOR SYSTEM TELEMETRY

The ID has certain characteristics which can be used to transmit telemetry to the system's users. Things such as emergency power, system maintenance, remote base turned on, or other things, can all be "announced" by the system ID circuitry.

Table 21-1. Matrix programming for the WA9EXP IDer.

Call: WA9EXP/RPT
# diodes used:

A	8	N	8	1	20
B	12	O	14	2	18
C	14	P	14	3	16
D	10	Q	16	4	14
E	4	R	10	5	12
F	12	S	8	6	14
G	12	T	6	7	16
H	10	U	10	8	18
I	6	V	12	9	20
J	16	W	12	0	22
K	12	X	14	Slant Bar	16
L	12	Y	16	Word Space	4
M	10	Z	14	Last Character	−3

International Morse code character duration in time frames. The values shown include the intercharacter space interval. The time duration of a complete string is therefore 3 frames less than the sum of the frames for its characters.

START →

View from Rear (Wire side) of PC Board

1		X		X	X	X		X	X	X				X		X
2	X	X				X	X	X		X	X	X		X	X	X
3	X	X	X		X				X				X	X	X	
4	X		X		X	X	X				X		X	X	X	
5	X	X	X		X				X	X	X		X		X	
6	X	X	X		X				X		X	X	X		X	
7			X		X	X	X		X	X	X		X			X
8	X	X														

Block out one square per diode. 127 bits available.

INSTALL 1 diode for Dit
3 diodes for dah
1 open = characters Space
3 opens = letter Space

Diodes indicated by an X

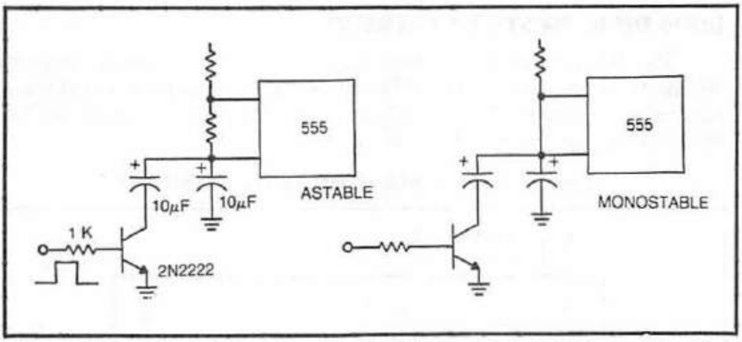


Fig. 21-11. A method of changing the speed of an astable oscillator, or changing the period of the monostable circuit.

How? Well, let's look at the ID sequence. We have the ID speed, ID tone, ID spacing, and the ID code; any characteristic or combination of characteristics can be modified to tell us something.

The IDers in this section use 555s as clock generators. The circuit in Fig. 21-11 can be added to any of them to change the code speed.

The method of changing the ID-tone frequency will vary with the design of the tone oscillator. If a filtered 555 output is used, you won't be able to change the tone without losing the filter action, The author's ID oscillator is shown in Fig. 21-12, along with the method used to change the tone. Make sure that the ID level does not change with the frequency change.

The ID spacing can be changed in the same way as the speed—both use 555s.

The ID code can be changed by one of a number of methods. The first is just to change IDers. This is a bit expensive, since two units would be needed. A second technique is to change to a second ID matrix. This is shown in Fig. 21-13. A third method could be just to change stop points—

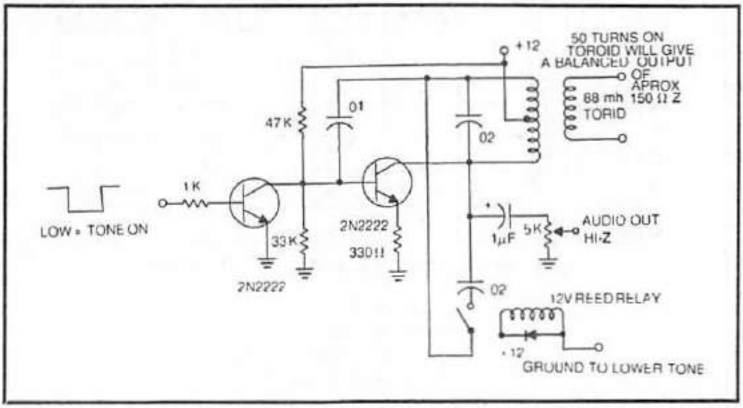


Fig. 21-12. Tone-changing circuit for the audio oscillator of Fig. 21-1B.

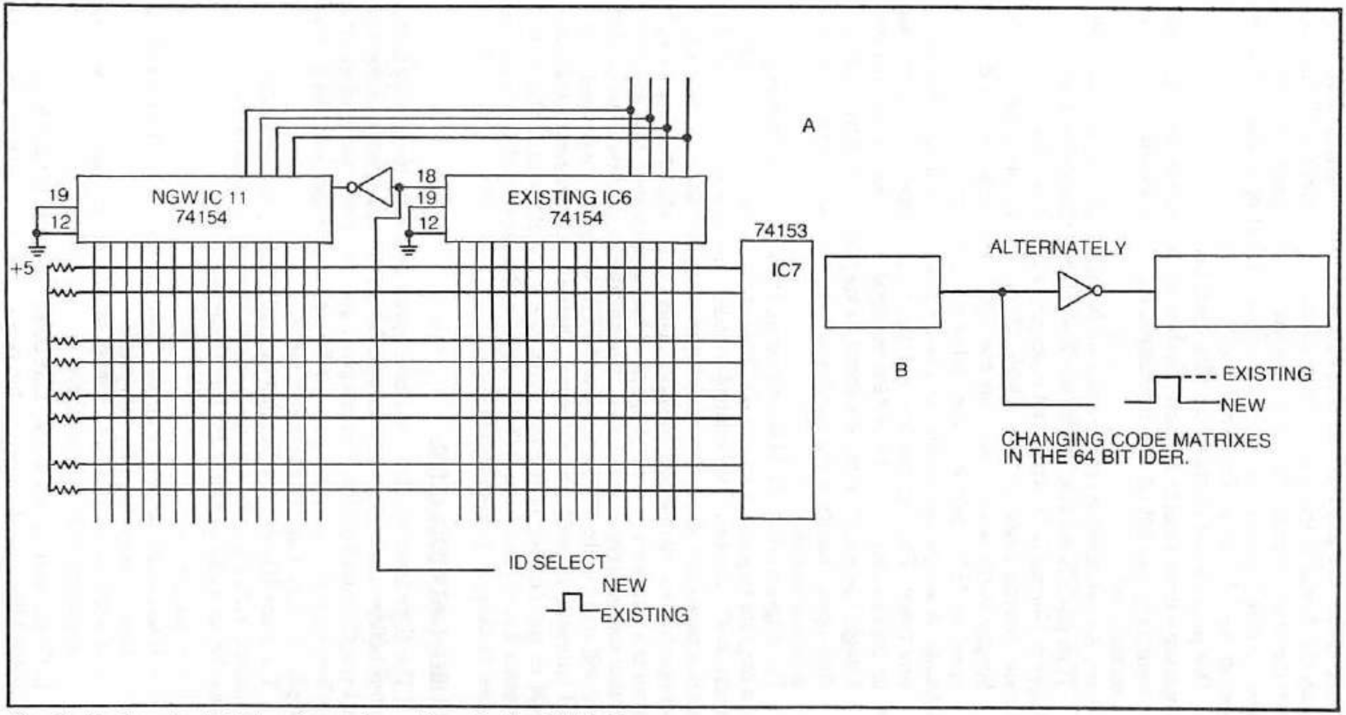


Fig. 21-13. A method of changing code matrixes for the 64-bit IDer.

the one shown in Fig. 21-4D has that option. A fourth method could be to modify the design to use a presettable counter, and start the ID partway down the code stream. This could tell the control operators something without telling the users, if the code stream was set up properly. Maybe leave off the DE" from "DE WR6ASD."

One possible set of characteristics could be:

ID spacing—from 3 min to 1 minute: System is not "normalized"—perhaps something was left off that normally is on, or something is on that is normally off.

ID tone: An indication of remote-base on. Normal tone is remote base off. High pitch is monitor mode, and low pitch is transceive mode.

ID speed: Normal is 10 wpm, and emergency power is 20 wpm.

ID code: Normal might be "DE WR6ASD" or "DE WA6ILQ/RPT". The burglar alarm would take away the "DE," and if the cabinet door is open, an "E" is added to the end of the code stream.

ID double: A simple modification to the IDer can result in the code being sent twice. This can indicate that the maintenance crew is working on the repeater, that the system is available for normal use, but that it might "go away" with no warning. One possibility, if the "cabinet-door-open" feature is not used, is to wire the double ID into the door interlock switch.

The diagram in Fig. 21-14 is not designed to be a construction diagram, but a diagram to present an idea—a "how many functions did the system actually do?" counter. The control-decoder systems presented in the previous pages are all capable of doing as many functions as the control operator desires, on one transmission. Many times, when running through a system's functions, a control operator has no indication that any given function was actually accomplished. The function-done counter presented here will count up to 15 functions, and then, when the control operator's PTT button is released, wait a moment, then give him a number of "beeps" equal to the number of functions that were actually done. This circuit presents a very basic form of "telemetry," and is presented just to get the reader thinking and experimenting.

THE IDER TONER OSCILLATOR:

The IDer audio oscillator has been given very little thought by many system builders, and this is unfortunate. A repeater has a captive audience, and a rough sound from the IDer can give a poor impression of an otherwise excellent system. Cervantes said it quite well in Don Quixote: "By a small sample, we may judge of the whole piece."

Too many IDer schematics that the author has seen use square-wave oscillators, either a 555, or a stable-wired 7400 gates. This is a very poor choice for an audio oscillator for three reasons:

- It sounds bad.
- It has audio harmonics up and down the spectrum. If a user has a tone decoder the Ider may trip it.
- It may cause adjacent channel interference. This can best be explained with an example:

Let's say that in location X, that there has been a 146.25/85 and a 146.28/88 MHz repeater running for years, with no trouble whatsoever.

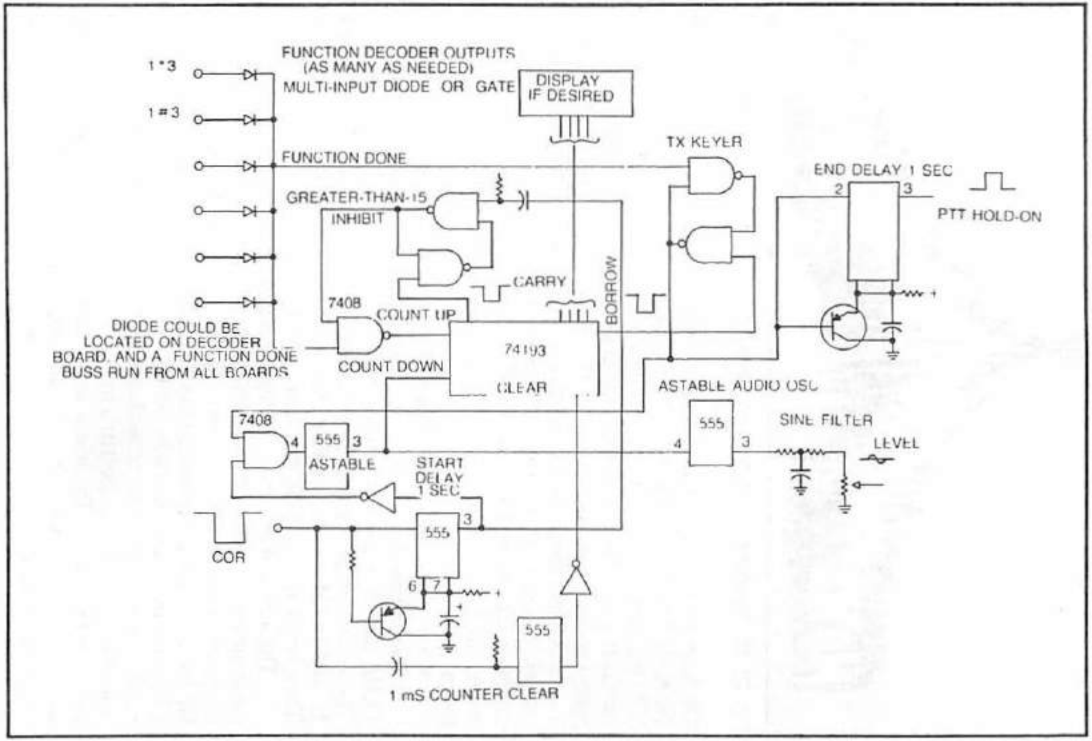


Fig. 21-14. A "functions-done" counter.

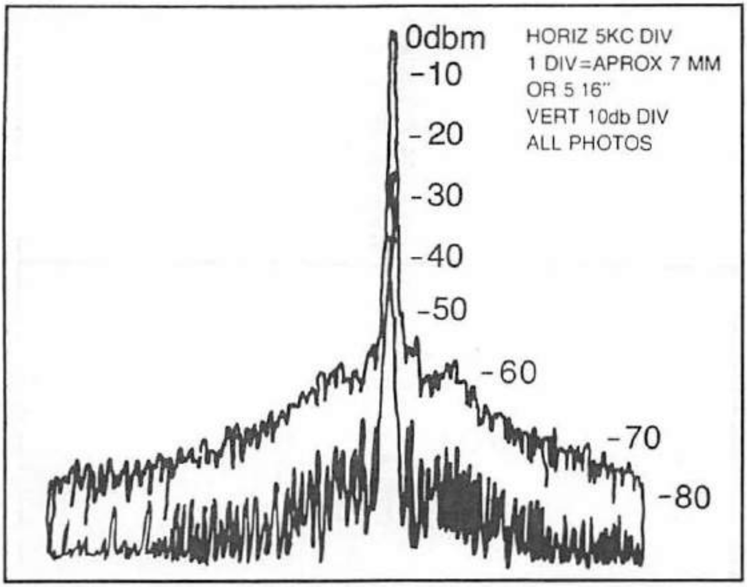


Fig. 21-15. Spectrum analyzer photograph showing unmodulated carrier.

The local coordinating council has just assigned 146.865/265 to "Joe Ham, WB6ZSY," and Joe has built WB6ZSY/RPT. He has built an IDer (with a 555 tone generator) from an article he saw in a magazine. He has been very careful to set up his audio circuitry with a compressing amplifier, so that the repeat audio level is linear, ,and the ID tone is approximately 1 kHz, and the level is 3 KHz. He hooks up his machine at its site, and turns it on. All of a sudden, there is this strange "kerchunking" on the 25/85 and 28/88 machines whenever Joe's machine IDs. A weak carrier on either machine during the kerchunking results in a perfect MCW "WB6ZSY/RPT" being heard.

Whats happening? Why is Joe's IDer clobbering the adjacent channels?

The square-wave audio tone contains the base frequency, in this case 1KHz, and all of the odd harmonics, ie, 3, 5, 7, 9, 11, 13, 15, 17kHz, etc. These frequencies modulate the carrier along with the 1 KHz, and the 13, 15, and 17 KHz products fall into the passband of the .25 and .28 receivers. They break the squelch, and therefore are repeated.

The author was fortunate enough to gain access to some good equipment, including an HP 8640B signal generator, which has FM modulation capabilities, *and a deviation limiter settable to 5 kHz*. It was set up with an HP 3311 function generator set to kHz, sine wave, and square wave. An HP 140S spectrum analyzer was hooked up to the generator, and a set of photos were made. The unmodulated carrier is shown in Fig. 21-15 the sine-wave modulation spectrum in Fig. 21-16, and the square-wave modualtion in Fig. 21-17. The levels were carefully checked before the photos were taken, to make sure that any differences were due only to the modulation changes. Remember, the generator was set up to simulate a

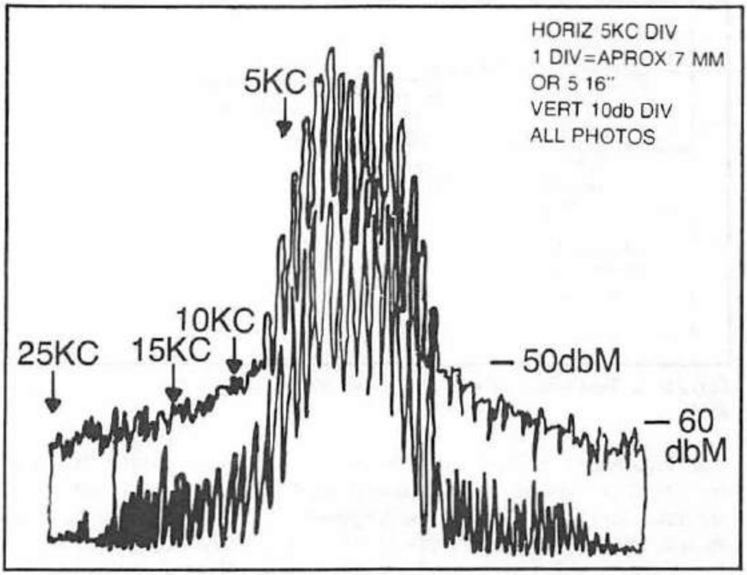


Fig. 21-16. Modulated by 1-kHz sine wave, 3 kHz deviation.

narrowband transmitter. See Fig. 21-18. The RF level was maintained at 0 dBm, and as shown there is a signal level of -30 dBm 15kHz away from the center channel. This is equivalent to 100 mW, if the main channel output is

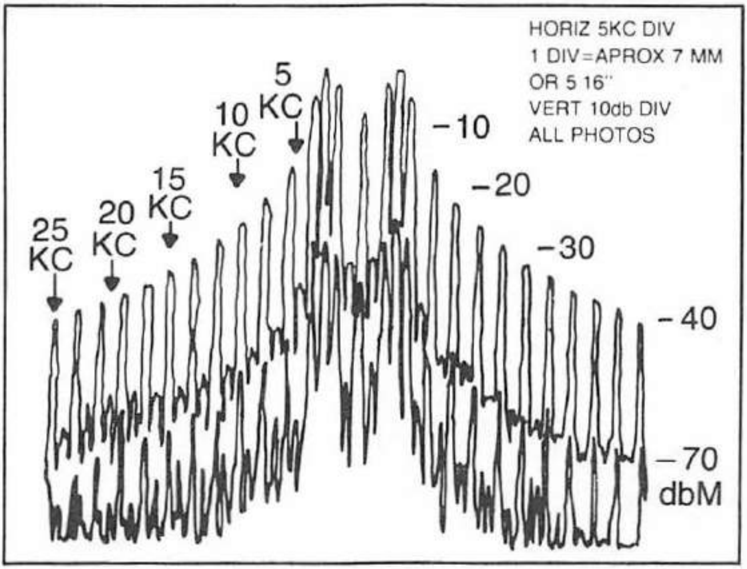


Fig. 21-17. Modulated by 1-kHz square wave, 3 kHz deviation.

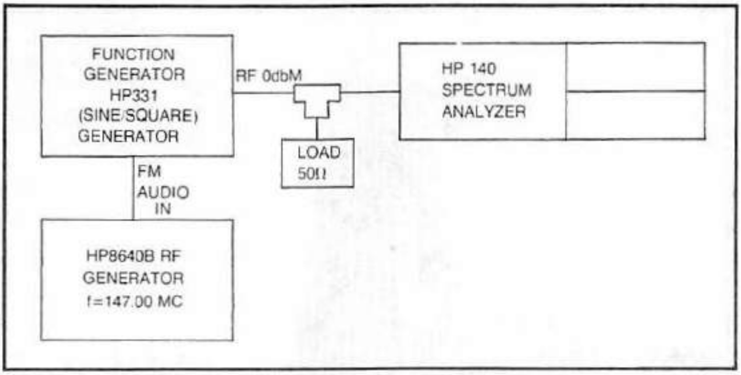

FUNCTION GENERATOR HP331 (SINE/SQUARE) GENERATOR
RF 0dbM
HP 140 SPECTRUM ANALYZER
LOAD 50Ω
FM AUDIO IN
HP8640B RF GENERATOR f=147.00 MC

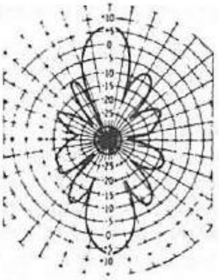
Fig. 21-18. Test setup used to obtain the photographs of Figs. 22-15 through 22-17.

100 W. Granted, this isn't much power, but when you consider that most repeaters are set up on the highest sites in a given area, with good antennas, and the best receivers, the possibility that 100 mW could get into an adjacent channel machine are better that you might think.

Cavities, either by themselves, or in the form of a duplexer, will help to cut down the level of these spurs, but why ask for trouble, when a simple sine-wave oscillator in any tone-generating device in your machine will eliminate the chance of said trouble?

Chapter 22

Solving Those RF Interference Problems



This chapter is devoted to solving the kind of problems that any new repeater/remote owner will face. Usually, these problems will manifest themselves the moment the system is placed into initial operation. However, some may show up after years of problem-free operation. There are two ways to find a solution to any problem. One is the "Hunt and Peck and Cuss" method, while the other is the scientific approach. While the former has proven of some limited success in the past, utilizing the latter approach is often more successful.

There are a number of different types of interference that a system is susceptible to, such as:

- Desensitization
- Intermodulation distortion (IMD)
- Adjacent-channel interference
- Various other forms of RF noise
- User abuse and malicious interference

RF interference problems occur in the commercial-radio field every day. If, by chance, your group is lucky enough to have a member who is a two-way radio technician, or if you have a friend who works for a two-way radio shop, you have a distinct advantage. Solving such problems is a part of any two-way technician's job. Also, two-way radio technicians usually have access to the type of test equipment necessary to properly track down these troubles; equipment that most Amateurs do not possess.

DESENSITIZATION

Desensitization becomes of greater concern as the frequency of repeater operation decreases. Where a 450-MHz repeater may encounter no measurable desensitization at all, a two-meter or six-meter repeater at the same site may be so plagued with it that useful operation at reasonable ranges is made totally impossible.

Desensitization is, without doubt, the most common single source of problems with repeaters. It is a phenomenon whereby a repeater receiver suddenly loses sensitivity when the repeater transmitter is energized. Like any other source of electromagnetic interference, desensitization can nearly always be significantly reduced. The likelihood of desensitization problems can be minimized at the outset through sound engineering and design practices.

Desensitization Characteristics

In a typical case of repeater desensitization, the transmitted signal causes the limiter current of the receiver to increase. Effectively then, the incoming signal is forced to compete with the repeater transmitter for control of the receiver. The transmitted signal will not have the characteristics of a signal, however, because it does not generally quiet the squelch. So here is what happens when a weak repeater input signal appears: The weak signal is picked up by the sensitive receiver, whose carrier-operated relay pulls in to turn on the transmitter. As the transmitter is energized, the receiver limiter current rises appreciably, and the receiver is no longer as sensitive as it was. The sudden drop in sensitivity might render the input signal totally uncopyable, and the receiver appears to be receiving an excessive amount of noise. The noise amplifier then tightens the squelch , shutting down the receiver. When the squelch closes, the carrier-operated relay opens to release the transmitter push-to-talk, and the transmitter shuts down. Once the transmit signal is gone, the receiver is again sensitive, and weak signal is again apparent. So the cycle repeats continuously as long as the input is in the very-weak-signal range. Now that we understand the problem at hand and know how to recognize it's symptoms, what can be done to correct it? Here are some time-proven suggestions. I say time proven in that they are the work of research on the part of Ken Sessions, K6MVH, and most were printed in the original 1969 version of this book. The techniques described are as valid today as they were ten years ago. Time has proven this to be so.

One of the most effective methods for beating the desensitization problem is careful placement of transmit and receive antennas. Attenuation of the unwanted transmit signal is best achieved by separating the two antennas from one another to the greatest extent possible. Since the radiation angles of the two antennas are ostensibly outward, maximum isolation is achieved by vertical separation. The curves of Fig. 22-1 show the attenuation in decibels that can be expected on the three primary amateur bands by separation in both horizontal and vertical planes. In all cases, the antennas used for the calculations were unity-gain vertical antennas with omnidirectional radiation characteristics. Omnidirectional "gain" antennas offer even better separation possibilities than groundplanes and coaxial verticals when the separation is not in the exact vertical plane, because of the considerably attenuated radiation above the horizon. Figure 22-2 shows typical vertical radiation patterns for a groundplane and a 5.8-dB gain collinear antenna. Note that the collinear antenna obtains its gain by virtue of its reduced vertical radiation; the doughnut-shaped radiation pattern of the groundplane is flattened by the gain antenna to yield a maximum signal at a plane perpendicular to the axis of the antenna. The "absolute" vertical isolation of groundplanes is typically better, however, than that of the gain antennas. (It may be better to separate gain antennas by moving one slightly off the axis of the other —horizontally or vertically—based on your own empirical measurements.) The intense output of the gain antenna at ninety degrees makes horizontal separation a nearly hopeless arrangement for single-site use, although excellent results can be obtained by one of the two antennas at a horizontal distance, then up a few degrees above the other's prime radiation pattern.

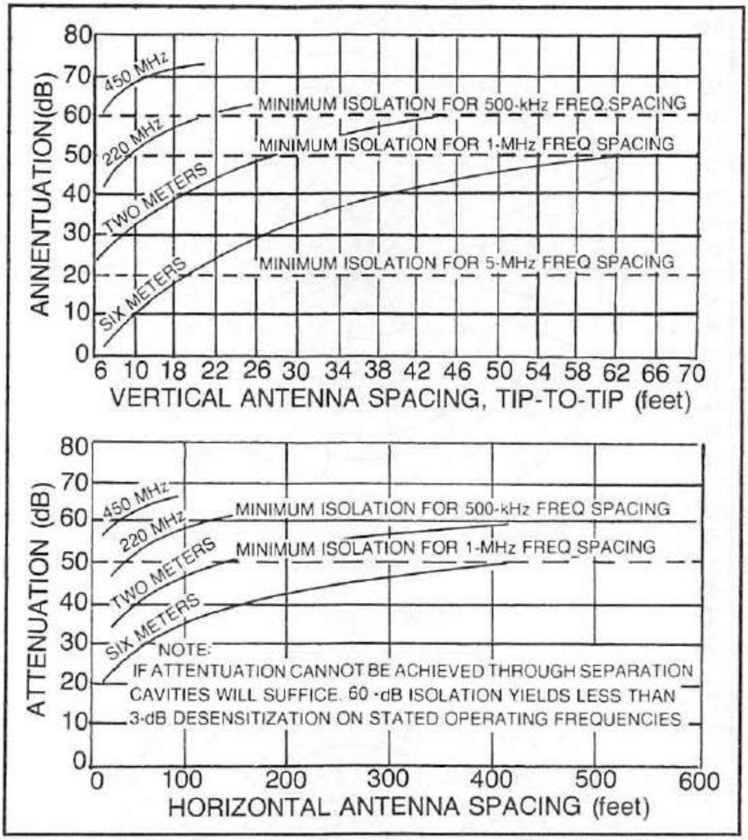
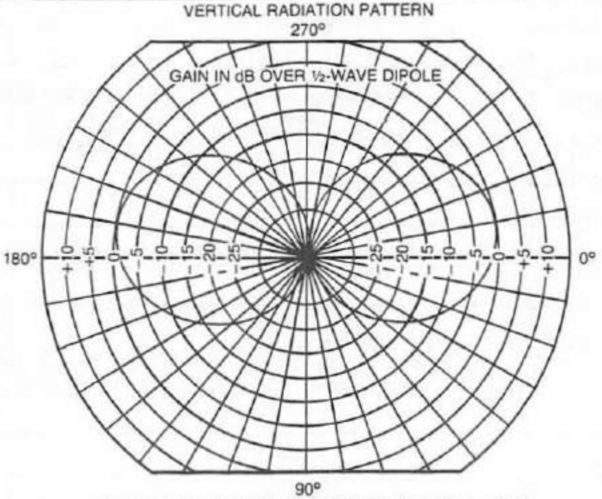


Fig. 22-1. Isolation that can be obtained by vertical and horizontal separation of antennas.

Where efforts to reduce desensitization to a nonharmful level fail, more drastic measures can be taken. Since these advanced measures require considerable time and effort, it is usually wise to check out all the "standard" techniques first. For example, it would be foolish to concentrate on minimizing desensitization at the antennas when the problem might be rf getting directly into the receiver circuits from "the inside."

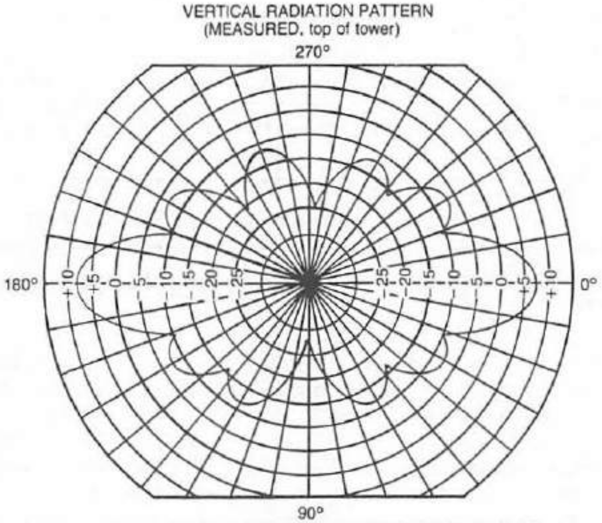
To determine the source of the problem, connect a sensitive meter to the receiver first-limiter test point and take a reading without keying the transmitter. Then key the transmitter and note the difference in the meter indication. Next, disconnect the antenna from the transmitter and attach a good resistive dummy load (with low VSWR) to the transmitter. If the problem is as bad (or worse), you can forget about antenna placement, because the odds are now in favor of trouble with the receiver circuitry.

You can double-check this by reconnecting the transmitter to an external antenna and connecting the dummy load to the receiver terminals.



ATTENUATION AT VERTICAL SEPARATION OF 5λ -55 dB
ATTENUATION AT HORIZONTAL SEPARATION OF 5λ - 35 dB

(A) UNITY-GAIN GROUNDPLANE.



ATTENUATION AT VERTICAL SEPARATION OF 5λ-42 dB
ATTENUATION AT HORIZONTAL SEPARATION OF ⅝λ -26 dB

(B) 5.8-dB GAIN PRODELING OMNI-6.

Fig. 22-2. Vertical radiation patterns for typical ominidirectional antennas.

(This minimizes the chances of stray radiation entering the receiver at this point.) Transmit again and watch the limiter monitor. If the reading has shown no significant decrease in value, it is time to do some shielding (or resurveying of various operational frequencies).

The need for shielding of repeater components may be so slight in the UHF range as to be insignificant, but at the lower frequencies it becomes unavoidable. There are two very important reasons why shielding requirements change with frequency. One is the fact that transmitter and receivers of a UHF repeater can be physically isolated by easily more than a wavelength in the same cabinet. (To offer a one wavelength separation on six meters, the cabinet would have to be more than 20 feet tall!) The second reason is frequency isolation. Where 450-MHz repeater transmit and receive frequencies can be separated by 10 MHz with ease, six and two-meter repeater frequencies are usually spaced by no more than 600 kHz.

It is beyond the scope of this handbook to describe the various shielding techniques. Suffice it to say that stray radiation from the transmitter must be prevented with the same zeal as the receiver is protected from ambient rf. Such shielding can be adequately effected by enclosing the transmitter and receiver in "radiation-resistant" screens. Most manufacturers of commercial FM gear make shielding kits to fully enclose their units when used in repeater service. These kits are usually inexpensive and allow a neat, tight fit over the chassis for which they were designed. If shielding is not the answer, and the limiter reading of the receiver indicates an improvement when either the transmitting or the receiving antenna is isolated, the problems must be countered from another tack.

Feedback Phasing

The use of receiver cavities is one effective method for reducing desensitization problems; but cavities of themselves are limited in their attenuation of unwanted frequencies. Often the transmit frequency is too close to the receive frequency to be adequately handled by a single cavity. In such cases, one can resort to a little trickery. Van R. Fields(W2OQI) successfullly "fooled" a repeater receiver into "thinking" there was no transmit signal present by designing a circuit that effectively canceled the transmit signal before it was processed by the receiver RF circuits. In his repeater system, the transmit and receive antennas were vertically separated by several wavelengths. A portion of his transmitted signal, emanat-

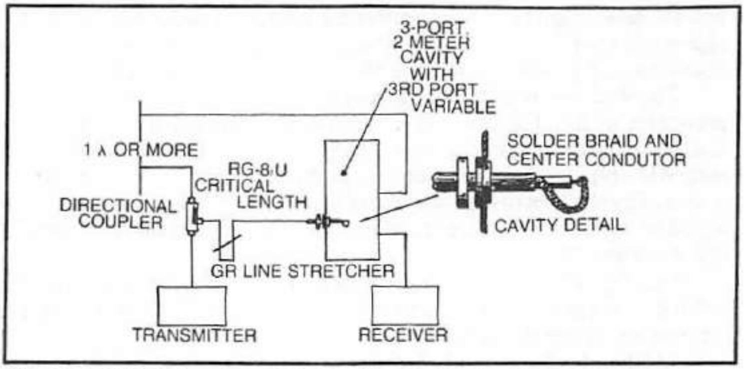


Fig. 22-3. Minimizing desensitization through feedback phasing.

ing from the lower antenna, was being "picked up" by the upper (receiving) antenna. So he came up with the plan shown in Fig. 22-3.

The idea behind this scheme is to introduce the same transmit signal directly into the receiver at the same amplitude but 180 degrees out of phase with the antenna-supplied signal. He did this by sampling the transmitted signal with a directional coupler, adjusting its phase with a line stretcher, and adjusting the critical length to the cavity. The cavity's loop was made variable so that attenuation without phase shift could be achieved.

To adjust, watch first-limiter current on a sensitive meter and turn the adjustable cavity loop to about 45 degrees. Next, adjust the line stretcher. A dip should be noted on the meter at some point. If the dip comes at the end of the adjustment(and it always seems to), add a small section of coaxial cable. It pays to have several short random lengths of coax available.

Once you have a dip, adjust the cavity loop for minimum limiter current. Once it is operating, the line stretcher can be replaced with a piece of coax of the proper length. Trimming can be accomplished by adding connectors or adapters.

The W2OQI approach represents a satisfactory and relatively simple solution to the problem of receiver desensitization, but it, too, has its limitations. Since effective cancellation depends on the critical phase separation, high winds or other unstable conditions at the site would be disastrous. It is necessary to keep the two antennas rigid so they will not move with the breezes. Also, the system must be moisture proof. If the VSWR shifts on a damp night, the phasing is out, and so is the repeater.

Hybrid Loop Duplexing

Of all the methods for defeating desensitization, none quite compares with the duplexing concept, whereby one antenna is used for the simultaneous operations of transmit and receive. Construction of a duplexer is complicated by the requirement for several cavities and by the close tolerances that must be adhered to in fabricating the various critical elements. But the result is what counts, after all; and a good duplexer can give an overall insertion loss of less than 1 dB. Adding to the duplexer's appeal is the renewed purchasing power of the repeater's "antenna fund." Where two antennas might have been planned for a duplexer needs but one. So the repeater owner has the pleasant task of choosing to buy a better antenna than originally planned or to save the cash for other eventualities.

The duplexer of hybrid loops and cavities described herein was first publicized in the Toronto FM Communication Association Bulletin, of Canada, and later in FM Magazine. The designer, Gil Boelke (W2EUP) has earned the reputation of being not only a gifted engineer but a prolific writer as well. Any changes to Gil's wording of the duplexer's theory and operation would be an injustice; for this reason, it is presented verbatim (except for figure numbers):

"As Fig. 22-4 shows, a hybrid loop is a 1.5-wavelength section of low-loss coaxial cable with ports at strategic places to allow access and termination of the rf signals.

"At the pass frequency ($f_1$1) the cavity is series-resonant, providing an effective short circuit at the cavity port (B). Counterclock-wise-traveling rf

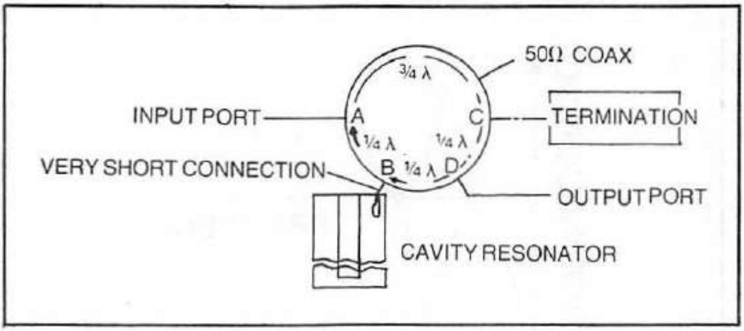


Fig. 22-4. Hybrid loop dimensions and terminations.

power thus meets a short circuit after traveling one-quarter wavelength. The input end of this quarter-wave section then looks like an open circuit at this frequency.

"Power flow from port A is clockwise, then, since the counter-clockwise path looks like an open circuit. The characteristic impedance of the input line is continued clockwise, with negligible disturbance at port A.

"Assume for the moment that port C is unterminated and does not have any effect on rf power traveling clockwise past it. Clockwise-moving power from the input then continues past port C to port D. The coax from port D to B is one-quarter wavelength and shorted by the cavity at B. Therefore, an open circuit appears to the left of port D, and power flow continues out of port D to the load a f_1. The power flow path from port A to port D is achieved without setting up VSWR on the line at any point and, if the cavity loss is low, without appreciable attenuation.

"At the reject frequency ($f_2$2) the cavity is no longer series-resonant, but it is detuned and presents a nearly pure reactance at port B. Radio-frequency power now flows past port B toward the output port. In so doing it traverses one-half wavelength of coax, with a resulting phase shift of 180 degrees.

"Note that the phase difference between these two waves is 360-180, or 180 degrees. If the power contributions are equal from opposite sides of the output port, power at f_2 is completely canceled

"In practice power passing port B is distributed by the cavity reactance. If port C is terminated in an equal reactance of the same sign as that of the off-resonance cavity at port B, the output contributions are again equalized and f_2 is canceled at the output. A useful analogy is to compare the loop with a bridge circuit. Anything seen at port B must be seen at port C to balance the output at port D.

"At f_1, in practice, port C is not open, but rather terminated in a reactance equal to the cavity reactance at f_2. This disturbs the wave traveling to port D, setting up a VSWR in the coax back toward the input port. The cavity is then detuned from exact series-resonance enough to produce an equal VSWR in the other leg of coax to the input termination, port A. The reactances appearing on opposite sides of port A are equal and opposite, so they cancel at the input. This adjustment in turn has an effect on the balance of the loop at f_2, and reactance at port C must be retrimmed.

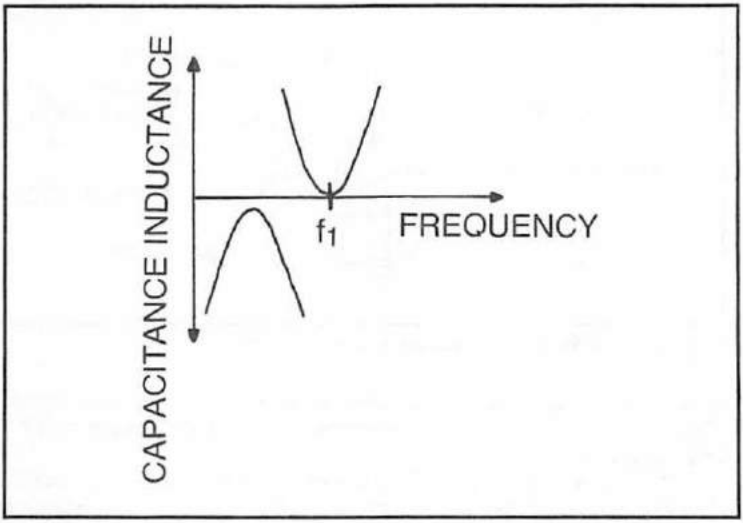


Fig. 22-5. Cavity characteristics with inductively coupled input.

"In the adjustment procedure the output power is maximized at f_1 by tuning the cavity, and the output power is minimized by adjusting the impedance at port C at f_2. Alternate adjustments will eventually result in a null at f_2 and a peak at f_1 if the cavity Q is high enough for the frequency spacing and the coupling is adjusted properly. If the insertion loss at f_1 is too high, it can be reduced by increasing the coupling in the cavity, and repeating the adjustment procedure. Too much coupling may prevent convergence of adjustment, and reduces the notch bandwidth.

"The value of impedance at port C depends upon the impedance of the cavity at f_2. The cavity, when coupled with an inductive coupling loop, varies roughly as in Fig. 22-5.

"A parallel-resonant point occurs at a frequency (f_3), slightly below that of f_1. This frequency may be varied by changing the coupling or inductance of the link. It is possible, when f_2 is lower than f_1, to place f_3 at f_1. At this point it is possible to eliminate port C entirely, since the necessary impedance is near infinity.

"For f_2 above f_1, the reactance becomes inductive, and it becomes capacitive only below f_3. If a parallel-resonant tank is placed at port C, one sweep of the tuning capacitor will cause a swing from inductive, through infinity, to capacitive reactance. This technique is very convenient when the required value is inductive, because it allows variation of the inductive reactance with a variable C.

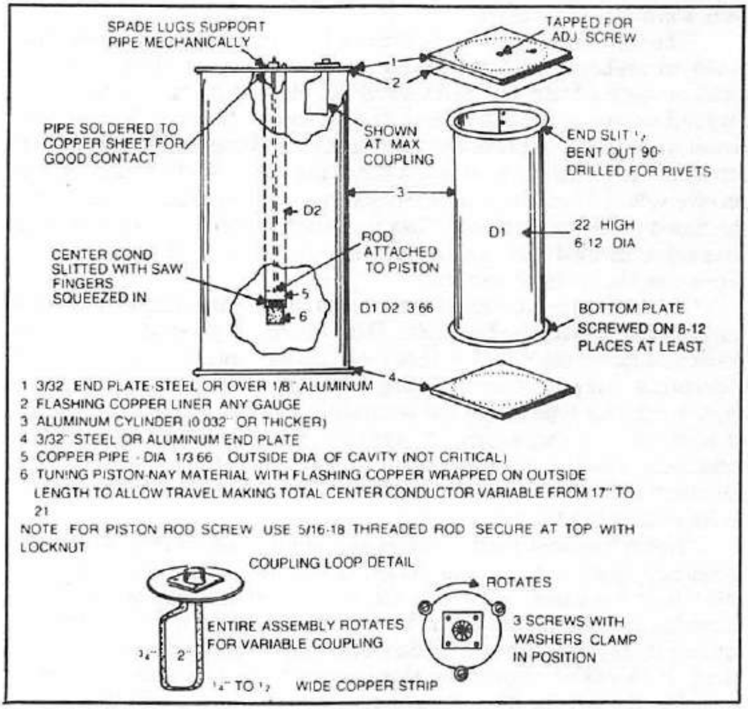
"In some cases it may be necessary to use some resistance at port C to achieve balance. This case occurs when there is some loss in the path past port B. A lossy cavity could cause it. With low-Q cavities, poorly cut loops, or close frequency spacing, this technique allows the system to balance at f_2, maintaining the full rejection of the cavity/loop combination, although compromising performance by resulting in a slightly higher insertion loss.

"The loop itself can be checked out by leaving ports B and C open, pumping power into the loop at port A. Very little power should come out at port D if it is cut properly. Remember that "end effects" on the coax joints can have a considerable effect upon the apparent electrical length of the lines. Shorting out either port B or port C should produce full output with little loss and a low-VSWR at the input. These checks should be made at some frequency between f_1 and f_2 preferably.

"There should be a negligible length of coax or lead lengths at ports B and C, expecially when checking the loop. Port B should be mounted right at the cavity without unnecesary lead length. Port C is not as critical in this regard to the adjustable impedance.

"Two other important points: With rejections in the neighborhood of 50 to 60 dB in a cavity, lack of shielding at any point in the system can negate the effect of the cavity and loop system. Shield everything completely except the antenna itself. Also, when testing the cavity/loop, the average transmitter used as a signal source may have enough spurious radiation or even ordinary transmitter noise to limit the rejection as read on an rf indicator. It may be necessary to filter the transmitter output with another cavity to make final adjustments!

"Fig. 22-6 shows construction details for a two-meter cavity with sufficient Q to be used with the hybrid rings. Four each of the cavities and rings are required to produce a system by which a single antenna can be


SPADE LUGS SUPPORT PIPE MECHANICALLY
TAPPED FOR ADJ SCREW
1
2
PIPE SOLDERED TO COPPER SHEET FOR GOOD CONTACT
SHOWN AT MAX COUPLING
END SLIT ½ BENT OUT 90° DRILLED FOR RIVETS
3
D2
D1
22 HIGH
6 12 DIA
ROD ATTACHED TO PISTON
CENTER COND SLITTED WITH SAW FINGERS SQUEEZED IN
5
6
D1 D2 3 66
BOTTOM PLATE SCREWED ON 8-12 PLACES AT LEAST
4
COUPLING LOOP DETAIL
ROTATES
ENTIRE ASSEMBLY ROTATES FOR VARIABLE COUPLING
3 SCREWS WITH WASHERS CLAMP IN POSITION
¾"
2"
¼" TO ½ WIDE COPPER STRIP

1 3/32 END PLATE STEEL OR OVER 1/8" ALUMINUM
2 FLASHING COPPER LINER ANY GAUGE
3 ALUMINUM CYLINDER (0.032" OR THICKER)
4 3/32" STEEL OR ALUMINUM END PLATE
5 COPPER PIPE - DIA 1/3.66 OUTSIDE DIA OF CAVITY (NOT CRITICAL)
6 TUNING PISTON-NAY MATERIAL WITH FLASHING COPPER WRAPPED ON OUTSIDE LENGTH TO ALLOW TRAVEL MAKING TOTAL CENTER CONDUCTOR VARIABLE FROM 17" TO 21

NOTE FOR PISTON ROD SCREW USE 5/16-18 THREADED ROD SECURE AT TOP WITH LOCKNUT

Fig. 22-6. Design details of a 144-MHz to 148-MHz cavity.

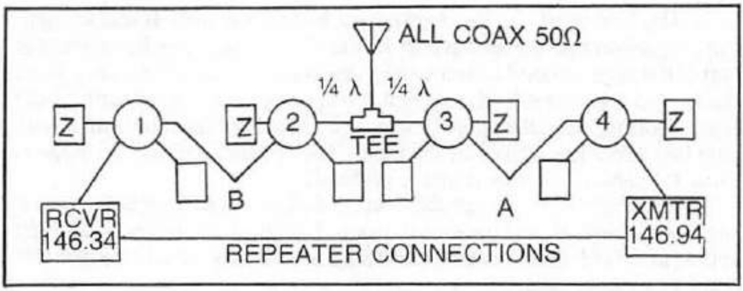


Fig. 22-7. Interconnection of loops and cavities for duplexing with a transmit frequency of 146.94 MHz and receive on 146.34 MHz.

used for both receiving and transmitting simultaneously. Fig. 22-7 illustrates the interconection of the elements for a 146.34-to-146.94 MHz repeater. (Figure 22-8 shows a typical receiver cavity.)

"A well designed preamplifier, such as a cascode FET type, can be placed at point B without getting overloaded. This placement is desirable because it reduces the duplexer loss on the receiver side to half. Similarly, it may be possible to install a power amplifier that isn't too noisy at point A, reducing the transmitter power loss in the diplexer. Experiment will tell which, if either, alternative connection is possible for the particular system with which it is to be used.

"The terminations (*Z*) can be coax stubs or tuned circuits. I prefer the tuned circuits because they permit the attainment of a perfect null, whereas stubs produce a finite dip. Stubs should be shorted, because open stubs may radiate unless the ends are shielded. I found that a parallel-resonant circuit worked best on the transmitter cavities, and that a 3K shunt resistor across the tuned circuit produced a null in the 70- to 80-dB range. On the receive side, I found that a series-resonant circuit worked better. Again, the tuned circuit needed some loss to make a perfect null. However,an alternative method was used, which is equally applicable in either the receive or the transmit cavities.

"By varying the LC ratio of these tuned circuits, the resitive portion of the resonant circuits can be varied. Thus, instead of physically inserting a resistor, I raised the effective *Q* of these circuits until they produced the appropriate amount of loss. Tuning is simply a matter of dipping the capacitor (piston type for smooth accurate adjustment), noting the amount of rejection, then squeezing or spreading the coil and re-dipping. The inductance value is readjusted until the signal disappears in the noise. Rejection is limited only by the stability of the adjustment and the bandwidth required of the notch.

"Notch bandwidth and insertion loss are the only limiting factors for frequency spacing. I was able to get 60-dB rejection and 1-dB loss at 300-KKHz separation. However, the notch width is small, and rejection degrades rapidly with deviations from the center of the notch. The 60-dB figure only represents the rejection level easy to attain in a quick adjustment. It should be emphasized that the notch depth is always unlimited except by the fact that it becomes more and more critical to adjust as it gets deeper, and obviously harder to hold there.

"My insertion loss measurements are not as accurate as I would like and I hesitate to quote them, but the rejections are reasonably accurate. Here are some figures: Pass 146.34, reject 146.94: Insertion loss less than 1 dB; rejections: at 146.940, 70 dB; at 146.928 and 146.952, 50 dB. Pass

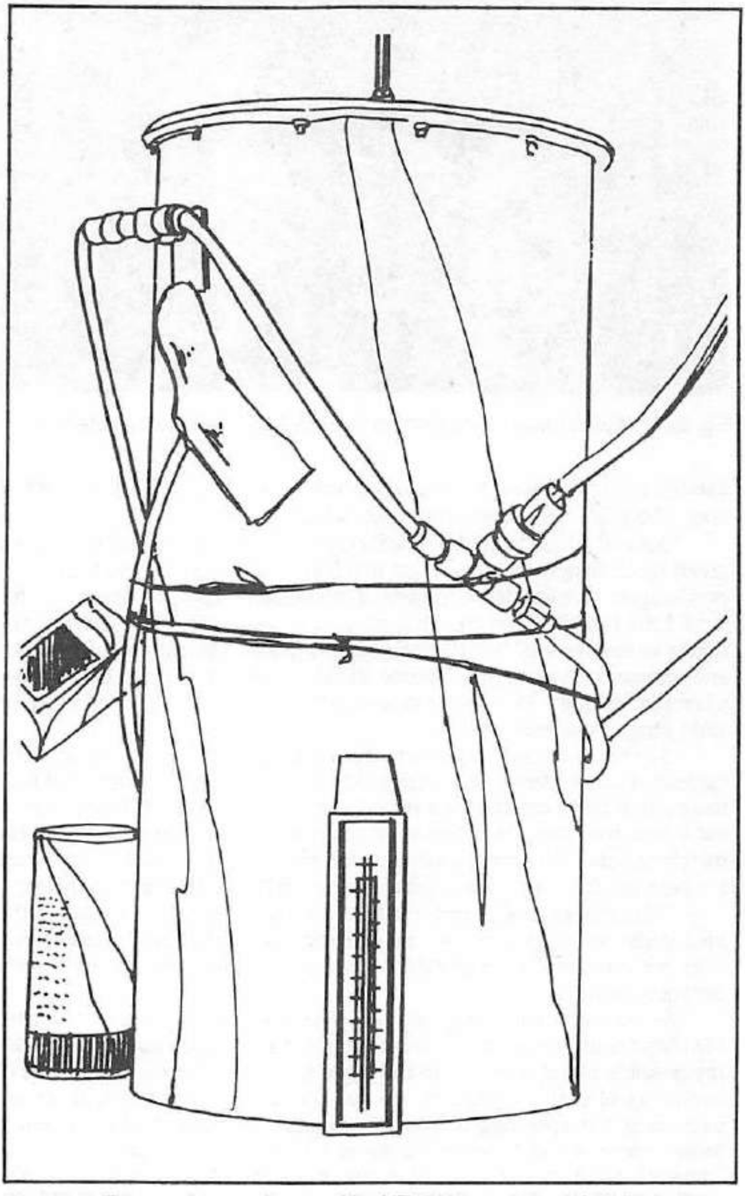


Fig. 22-8. This receiver cavity, used by VE3RPT, uses the W2EUP design.

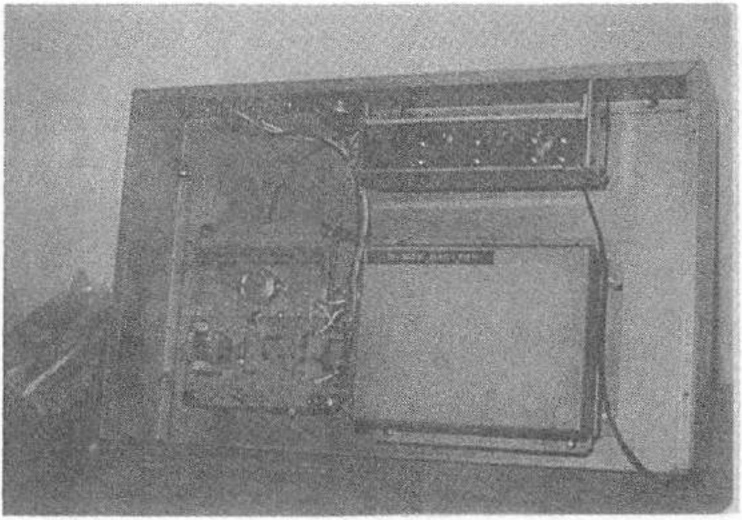


Fig. 22-9. Well-shielded transmitter in the WA6VQP repeater/remote base.

146.94, reject 146.34: Insertion loss 0.6 dB, rejection at 146.34, over 80dB (saw 100!); at 146.328 and 146.352; 50 dB.

"Miscellaneous facts: Low cavity Q results in a high insertion loss for a given notch bandwidth. Rejection notch still unlimited the oretically; depends upon stability and accuracy of adjustment. Use low-loss coax for loop. I tried small Teflon coax and got very poor results. Solid shield works better in the system. You'll need double-shielded coax at receiver output and transmitter input lines. Double-shielded cables also make good loops. Clamp loops down to prevent movement. Cavity coupling loops must be wide straps, not wire.

"For test purposes, a receiver makes the best rf indicator, with a good calibrated attenuator-type signal generator. Theoretically, the VSWR at the input of these cavity/loops at the frequency to which it is tuned is unity for a resistive load. In practice, it might be desirable to add a variable matching network to the system on each side because a cavity/loop tuned for best rejection may not exhibit a good VSWR at the pass frequency.

"With careful design and construction it is possible to combine all the best attributes, so that a single high-gain antenna and a lone run of low-loss coax will give results comparable to two such installations spaced a great distance apart."

As more and more equipment gets placed into service at a remote site, the chances of interference increase more than proportionately. Consider the possible signal sources: In the stand-by mode, there are local and i-f oscillators of nearby receivers and their respective harmonics, there are harmonica of transmit signal from other units in the area. And in the repeat mode, there are all these problems in addition to the signals caused by "mixing" of the transmit signal (or one of its submultiples) with one of the other stray signals. The list of possible sources some times seems endless.

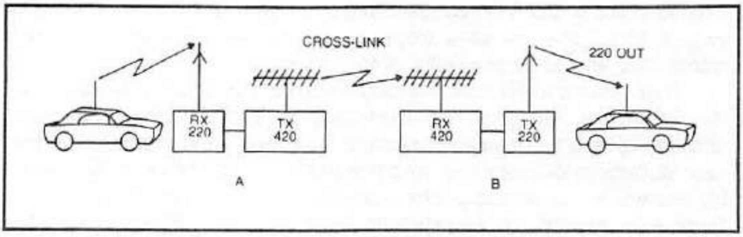


Fig. 22-10. A representation of a split-site repeater.

SPLIT-SITES

One of the most effective methods for defeating desensitization is the passive method of using two separate locations—one for the transmitter and one for the receiver. If the two sites are close enough to allow economical interconnection of the two sites with a wire line, but far enough apart to rule out possible desensitization, an ideal set of circumstances exists. (See also Wireline Control) A well-shielded transmitter is shown in Fig. 22-9.

To understand the whys and wherefores of Split-Site operation, we should refer to Figs. 22-10 and 22-11. Figure 22-10 shows a typical split-site repeater where the system's receiver is located on hill A. The signal appearing in that receiver is detected and fed to a linking transmitter, or wireline. The linking transmitter, if used is usually on a band such as 220 or 420 MHz, and the channel(s) utilized are coordinated through the local frequency coordinator or council. The RF from our linking transmitter, in our case on 420 MHz, is transmittted in the direction of hill B, using a directional antenna; usually one or more Yagis. At hill B, another directional antenna system is aimed at hill A and its linking receiver is tuned to the same frequency as the linking transmitter on hill A. What this receiver hears is detected and used to modulate the repeater's primary transmitter. Thus,

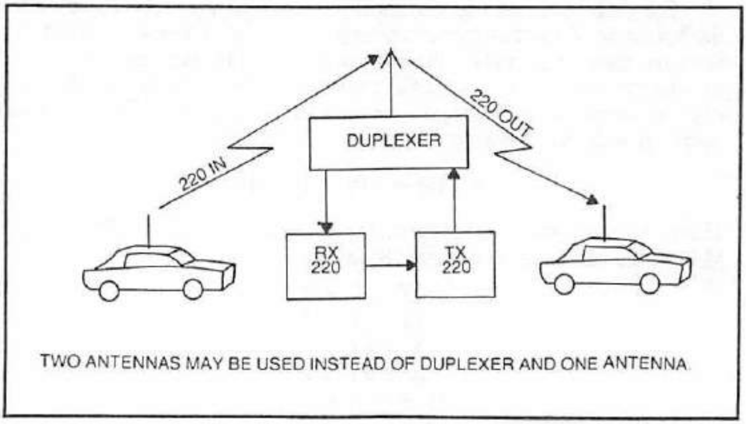

220 IN
220 OUT
DUPLEXER
RX 220
TX 220
TWO ANTENNAS MAY BE USED INSTEAD OF DUPLEXER AND ONE ANTENNA

Fig. 22-11. A single-site repeater.

what is heard on hill A is retransmitted from hill B. If the two sites are far enough apart, as most sites are, then no desensitization from your own transmitter should be prevelant in the system.

If this simple method seems too good to be true, and you wonder about the drawbacks, then fear not. Drawbacks do exist, the main one being different receive and transmit coverage. In other words, your receiver may hear stations in locations that your transmitter cannot talk into. Conversely, you will be transmitting into locations where you cannot hear. Then, there is the multiplicity of equipment. As shown in Fig. 23-11, a single-site repeater has but one site, transmitter, receiver and one or two antennas (one, if duplexer is used) to contend with for maintenence and upkeep. When you go the split-site route, you are adding at least one more site, two more antennas and another receiver and transmitter. Your initial and ongoing expenses will be doubled, if not more. Finally, there is the problem of securing two good sites. In the old days that might have been easy, but not so today—especially in crowded urban areas. Relay system groups are lucky to find one passable site, let alone two good ones that can "see" each other. When such can be found, the cost is usually prohibitive. Therefore, while split-site is a simple technical solution to the desense problem, it can be the hardest and costliest to implement.

INTERMODULATION DISTORTION OR IMD

IMD can easily be distinguished from other types of interference in that it sounds like two people talking on the same frequency at the same time. You may have heard this condition on one repeater or another and not known what it was. The FM community has a number of names for it, some unprintable, but the two most common are "Intermod" or "IMD". We shall refer to it as IMD.

IMD is caused by two or more signals combining to produce a third and unwanted frequency through a process known to all amateurs as mixing. The mixing process can take place in a system's receiver, transmitter, or even in a corroded antenna joint. To understand how the mixing process and hence the IMD problem occurs, we must delve into a bit of basic math.

For IMD to occur, a given fundamental frequency must combine with the harmonic of another frequency to produce our undesired product. To see what happens let's play a bit with some two-meter numbers. If we were to take the second harmonic of a transmitter operating on 145 MHz and subtract from it a transmitter/receiver frequency of 146 MHz, we would come up with the following:

$$(2 \times 145) - 146 = 144 \text{ MHz}$$

This is the mathematical representation for what is termed a "Third-Order Mix." This can be shown as the equations:

$$\begin{gathered} 2X - Y = Z \\ 2X + Y = Z \\ X - 2Y = Z \\ X + 2Y = Z \\ W \pm X \pm Y = Z \end{gathered}$$

Where W, X, Y, and Z are all frequencies involved.

There are 3rd, 5th, 7th, and 9th order mixes possible, and the basic formula above can be expanded to cover all of these, and more. An engineering text on this subject will contain detailed mathematical computations for each, and I suggest that you obtain one if further insight into the overall mathematical relationship is of interest to you. One rule of thumb to remember is that the most common cases of IMD are caused by the lower orders of mixing. Rarely will anything greater than a 5th order mix be your problem, though this does not mean that it cannot happen. Most common are the third-order mixes already discussed, and another type known as the "Non-Harmonic Related" mix. Here, it is two fundamental frequencies that are involved, and this can be expressed by the equation $X \pm Y = Z$. Let us suppose that an FM broadcast station at 98.0 MHz were to mix with a commercial service operating at 45.24 MHz.
Mathematically:

$$98.0 - 45.24 = 52.76 \text{ MHz}$$

If such were to take place in Los Angeles, the mix thereby created would have the ability to "wipe out" a very-wide-coverage, Multi-site, voting, six-meter system that operates with an input of 52.76 MHz. Starting to make a little sense?

It's easy to tell if you are dealing with a "Non-Harmonic-Related Mix" or an "Odd Order Mix" simply by listening to the quality of the audio of those signals involved. If both seem to be at the same level, then the mix is non-harmonic related. If the audio of one signal is louder than the audio of the other, the mix is "odd order". Why? Simply because each time the frequency is multiplied, so is the deviation. If we take the second harmonic of a 145 MHz frequency with 5-kHz peak deviation and look at the second harmonic, we come up with a frequency of 290 MHz and 10-kHz deviation. So, listen carefully, and in many cases your ears will tell you the story.

Another job your ears can do is to listen for callsigns or other station identifications that will lead you to the source of your problems, and hence the frequencies involved. Once you have the callsigns, a small amount of research should bring you the information as to transmit frequency and transmitter location. Don't be to surprised to learn that part or all of the IMD problem is coming from other transmitters at the same site. This is quite common.

Now that we have determined the other sources of the mix, we must look to our own system to see where it fits in. Most IMD mixes take place in receivers. Very few, if any, receivers have a front end so narrow as to see only the specific desired frequency we are receiving. Most see that and a lot more. IMD in a receiver takes place when two or more off-channel signals enter and saturate a receiver's RF amplifier or mixer. To find out if the interference you are suffering is truly receiver IMD, a simple but conclusive test is in order. The only piece of test gear necessary is a calibrated attenuator. Insert the attenuator between the antenna and the receiver input while monitoring local audio. If, as you increase the value of attenuation, the problem is reduced or eliminated, it is an IMD problem. However if the interference attenuates only to the dB amount of attenuation, then the problem is, actual on-channel interference that the receiver is hearing. That

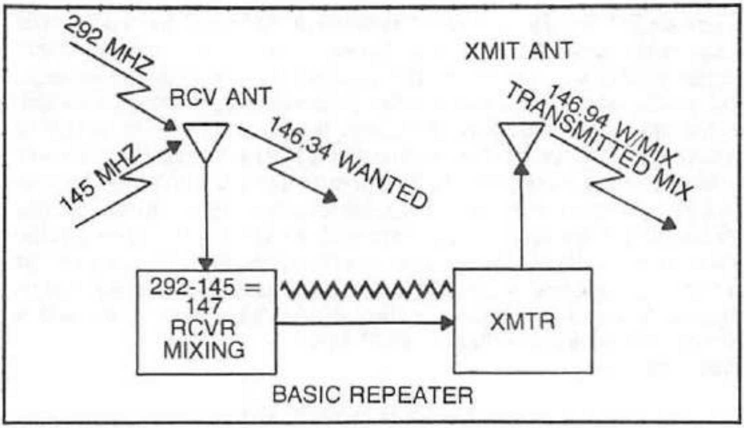


Fig. 22-12. Unwanted signals mixing in the receiver.

is, 10 dB of attenuation gives a 20 or 30 dB interference reduction, you can be pretty certain that IMD is the culprit. However, if 10 dB only rids you of 10 dB of interference, then look elsewhere. Also, be certain that the suspected IMD is not causing full limiting before you make this test, or you can easily be fooled. Some additional "fixed" attenuation inserted in the antenna line, while monitoring limiter current, will assure you that the test criteria are met.

The two basic tools for curing receiver IMD are cavity resonators and front-end crystal filters, inserted between the antenna and the receiver RF input. Figure 22-12 shows a basic repeater without any such features installed. Inserting a few cavity resonators Fig. 22-13 will tighten up the front-end selectivity, and make the receiver less prone to IMD problems, but the insertion loss of the cavities will lower your system sensitivity. For severe cases, a crystal-filter front end, with a preamplifier to restore the filter's insertion loss, is recommended, Fig. 22-14. In the most severe cases of receiver IMD, a combination of both types of filters may be required. Also recommended is an "output" cavity resonator in the transmitter line to minimize the transmitter RF leakage as being part of the problem. These techniques are illustrated in Figs. 23-13 and 23-14 respectively. Remember that, when using a cavity in the transmitter line, it is imperative that it be able to handle the power level of the transmitter in your system, or damage to both can result.

TRANSMITTER PROBLEMS

Speaking about the transmitter, it too can be a source of IMD problems. Virtually all FM transmitters use class-C final amplifiers, and a class-C amplifier makes an excellent high-level mixer. Suppose that another high-power station is operating close to your system. It is possible for some of that transmitter's radiated RF to be picked up by your antenna, travel down your transmission line and mix in your final amplifier. The IMD products of the other transmitter will be transmitted on your carrier. Figure 22-15 shows such a condition.

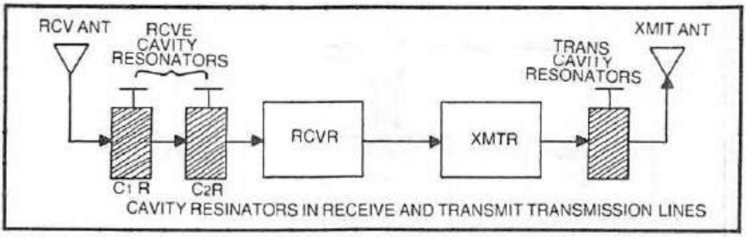


Fig. 22-13. One cure is to place resonant cavities in the receiver and transmitter feedlines.

How can you tell if the problem is transmitter-related IMD? First, perform the receiver IMD test as previously outlined. If the test proves negative, then you probably have either "transmitter" or "external" IMD problems. Does the IMD disappear when your transmitter drops off or when the other transmitter does? If so, then suspect it to be transmitter-related IMD. Finally, place a cavity in series with the transmitter and antenna, tuned to the transmitter frequency. If the level of IMD is reduced or eliminated, you have your proof.

Transmitter-cavity resonators are the easiest devices to try to cure transmitter-related IMD. If the use of such cavities minimizes, but does not completely eliminate, the problem, try separating the antennas a greater distance if such is feasible. The true solution is the installation of a ferro-magnetic device known as a circulator between the transmitter and antenna.

CIRCULATORS

A circulator (see Fig. 22-16) is a device made of ferro-magnetic material that will pass RF in one direction only. Therefore, should your system antenna be receiving RF from a nearby transmitter, it will get only as far as the circulator and there it will be stopped. However, RF energy from your transmitter will pass through to the antenna with very little attenuation; usually less than .5 to .8 dB. Circulators are very effective in treating transmitter IMD, however they are fairly expensive devices. Therefore, if a few surplus cavities capable of handling the total transmitter output power are available, try them first. If you can clean up the IMD that way, all the better. If not, and if you are sure beyond any doubt that transmitter IMD is the culprit, then the investment in a good circulator engineered specifically for your system may be in order.

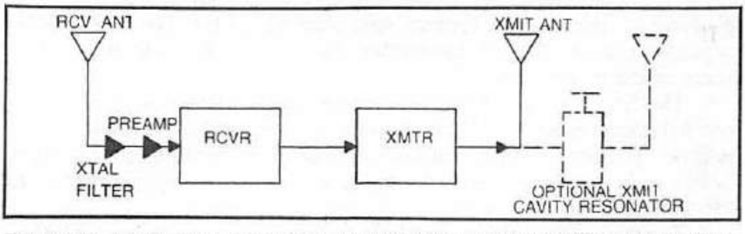


Fig. 22-14. Another cure is to place a crystal filter and preamplifier ahead of the receiver.

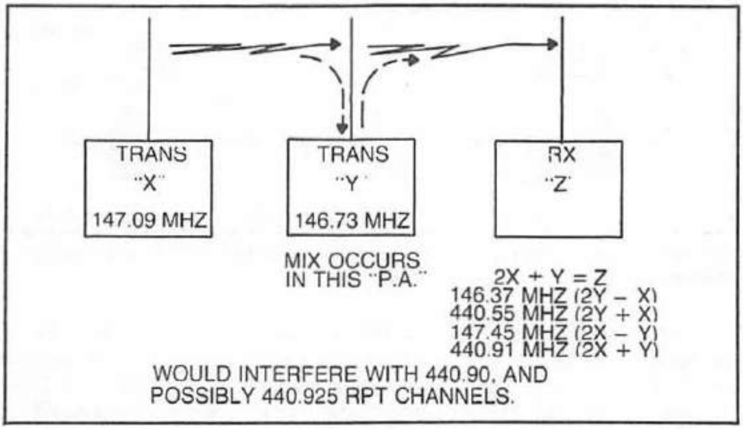


Fig. 22-15. IMD can be caused by signals mixing in the output stages of a transmitter.

You have eliminated both the receiver and transmitter as sources of IMD. What then? Monitor your receiver's limiter current and watch the IMD signal. Does it frequently change in limiter current reading? If so, the chances are that something outside the Transmitter and Receiver is the mixing point—a rusty tower bolt, or a corroded connector or antenna mount. Any such item can become a "semi-conductor" of sorts, and act as a mixer. One system I know of developed an IMD problem after years of operation. Tests were made, and both the receiver and transmitter proved clean. Inspection of the antenna guy wires showed them to be rusted. They were replaced and the IMD problem disappeared.

While you cannot be responsible for every antenna, connector, guy wire, and bolt at a densely populated site, you can keep your own act clean by keeping your overall system well maintained. Connectors should be kept clean and well protected from the elements. Rusty bolts and guy wires should be replaced as soon as they are noted. Periodically weather-protecting both the antenna and its mount are advisible.

ADJACENT CHANNEL PROBLEMS

If you happen to be the one and only repeater in your area, then it's doubtful if you have to worry about adjacent channel interference problems. In fact, this discussion is primarily oriented toward areas either using or planning to use, 15-kHz tertiary split channels in the 146 to 148 MHz repeater subband. If this is the situation that you must live with, then here is some useful information.

The first step in solving adjacent-channel problems is to rearrange one's thinking. When 15-kHz splits come into existance, the day of 30KHz is gone. The first 15-kHz coordination negates everything that has come before it. In essence, every system becomes a tertiary split in relation to the system 15 kHz away.

There are three things that help minimize adjacent channel interference.

- Terrain separation.
- Deviation level
- Receiver selectivity

Terrain separation is the direct responsibility of the coordinator or coordination council. If you fail to coordinate your system, and wind up sandwiched between two powerful adjacent-channel systems, the only person to blame is the one you see reflected in the mirror. The coordinator and/or council will have guidelines established for adjacent-channel separation in miles. You may not like the channel pair assigned to you, but trust their judgement and accept it. The chances are that due consideration was given to every aspect of your proposed new operation, and the minds involved in the decision-making process are privy to information you don't have.

Figure 22-17 shows how terrain blocking can be taken advantage of to reduce adjacent-channel problems. A mountain range, individual hill, or great distances (75 to 100 miles), can be used to "cushion" your system, and sometimes a superior site must be bypassed in favor of one which will provide the most trouble-free, if not the most desirable, coverage.

Depending upon the bandplan used in your area, you will either have the output of another system (inverted tertiary) or hordes of users (non-inverted tertiary) as your source of interference. Usually, it is easier to work with the inverted tertiary plan because it is a "one-on-one" situation between you and the other system owners. It is assumed that both parties are technically competent, and, moreover, that they will show the willingness to work together to solve this problem. Trying to locate possibly

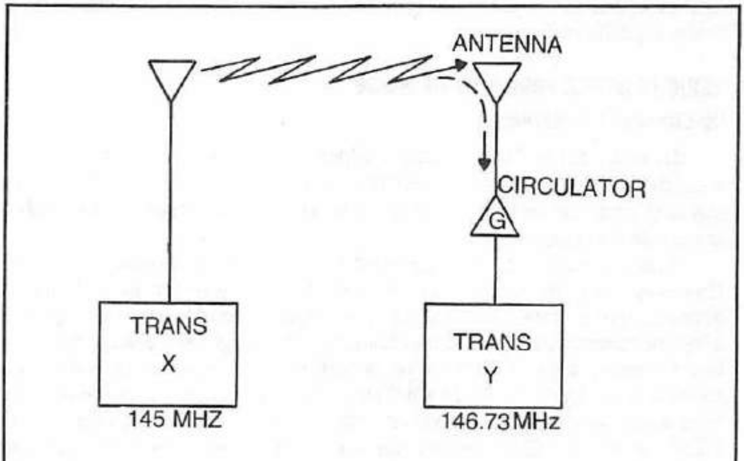

ANTENNA
CIRCULATOR
G
TRANS
X
145 MHZ
TRANS
Y
146.73MHz
INSTALLATION OF CIRCULATOR WILL STOP TRANSMITTER "X" FROM REACHING PA OF TRANSMITTER "Y"

Fig. 22-16. A circulator will stop RF from transmitter "X" from reaching the output stage of transmitter "Y."

hundreds of adjacent-channel users (non-inverted tertiary plan) can best be described as a nightmare not worth the attempt: there is but one solution—tighten up your receiver's selectivity and hope for a miracle.

Adjacent-channel interference is probably the easiest of the categories to prove. If you suspect it's happening to your system, go to your site with a synthesized radio and look 15 kHz either side of your receive channel. If it's there, you will find it. The best place to begin is in your receiver's I-F amplifier (low I-F in a double-conversion type). The simplest way to increase selectivity is to change the receiver's I-F filter for one with a sharper curve and narrower overall bandwidth. On some older radios, this may not be possible, and in such cases replacement of the system's receiver might be required. Even then, you may never be able to totally eliminate the problem. However you can make it tolerable.

The other system or users can help by cutting back their deviation so that it peaks at less than the now nationwide standard of 5 kHz; even a 0.5 kHz drop will work wonders. Here in Southern California, we try to convince adjacent channel repeaters to peak out at 4 to 4.5 kHz. This decrease in deviation will effectively lower the sideband power of the interfering transmitter(s). This may not be practical in areas where right-side-up split-splits are used, since controlling the technical standards of hundreds of user radios may be impossible.

There are other ideas that can be implemented on this topic, and I wish to call your attention to appendix of this book. In it, you will find papers by Bob Thornburg, WR6JPI, and others, that go into this problem in more detail.

In the end however, only proper technical standards, judicious coordination, and total cooperation can effectively solve adjacent-channel interference problems.

VARIOUS OTHER FORMS OF RF NOISE

Co-Channel Interference

In some areas "clear-channel allocations" no longer exist. Once an area runs out of available spectrum, it has but one alternative: begin stacking systems on top of one another on the same channel pair. This is known as co-channeling.

Many methods have been tried for effective co-channel operation. However, only two can ever really work. First, where terrain and mileage permits, use distance and natural geographic boundries as is done with adjacent channel coordination techniques. This might not always be possible. Consider areas where there is high-density repeater operation and absolutely no form of terrain shielding. There is but one possible answer: tone access. Controlled receiver-entry systems such as CTSS, Digital CTSS, or Burst will permit the users of your system to key up only your system, and the other systems users to key up only their system. It will not result in non-interference between the two systems, since, if both have the same service area, both will interfere with one another. However, if each of the systems involved provides itself with a lockout receiver listening for the access tone of the other system, and locks itself out of operation while the other is operational, they'll have a form of automatic time sharing. In crowded urban areas, no better solution exists than selective-tone access.

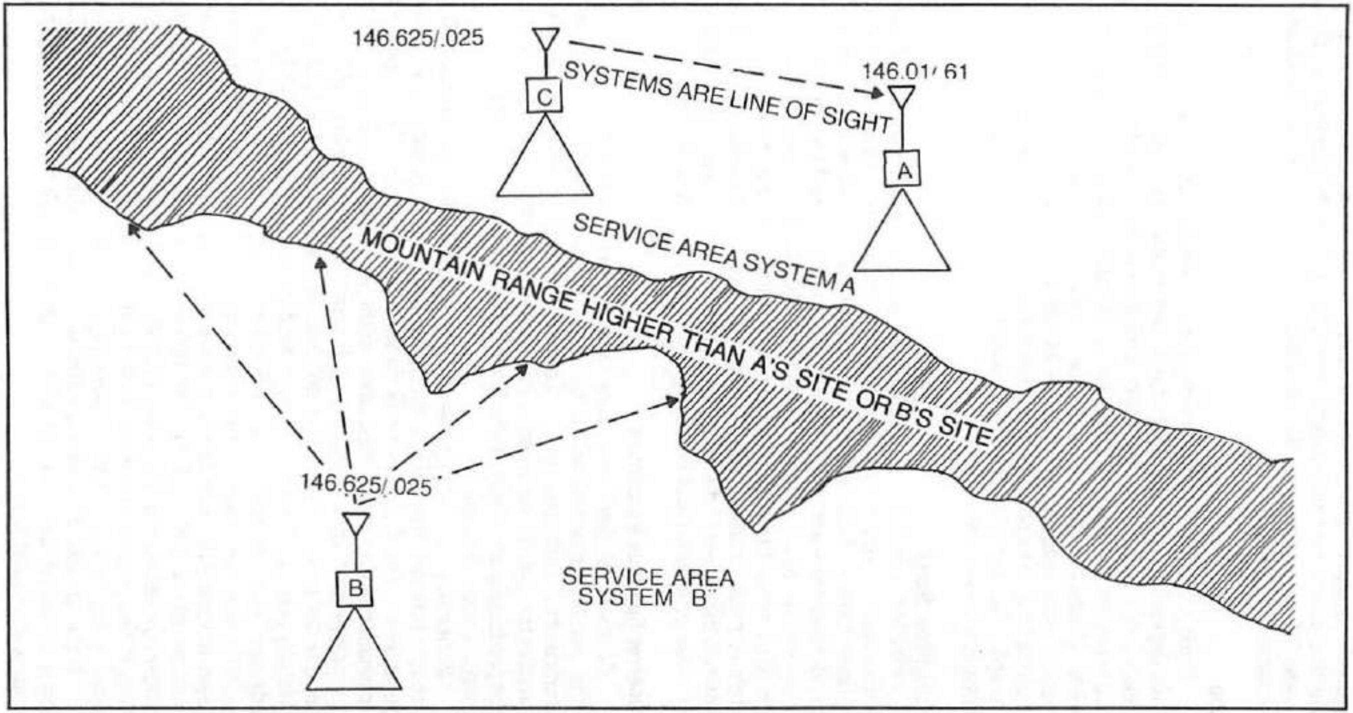


Fig. 22-17. A mountain range will isolate system A from B, but A can cause problems at system C.

Figure 22-18 shows how this is done, and complete information on the many selective-access systems available are to be found in the chapter on "Tone Access." This works—in L.A., one channel is used by 7 systems, all with the same service area.

Skip

During "peaks" in the eleven-year propagation cycle, and at other times dependent upon the time of year and weather factors, systems and users many hundreds of miles away can interfere with communication on a local repeater. This is especially true of 10-meter and 6-meter operations due to "E" and "F2" propagation. This condition has been reported over the years as even reaching up to 146 to 148 MHz, although not for any great length of time. The only effective cure is tone access to prevent unwanted key-ups, and many coordinators/councils insist that all 28-and 50-MHz repeaters be so tone equipped.

Transmitter Noise

All FM transmitters generate wide-band noise which may degrade the performance of your receiving system. In many cases, this problem may manifest itself with the same symptoms as receiver desensitization, and therefore all tests normally made for this condition should be employed. If all tests prove negative, then a search should be made—with the cooperation of all other site users—for the transmitter causing the problem. To effectively cure transmittter noise, one or more cavities must be inserted between the output of the offending transmitter and its antenna. Transmitter noise problems must be cured at the offending transmitter.

Receiver Spurious Responses

Receiver spurious responses can come from a variety of sources. They can be generated within the receiver itself due to poor design, insufficient internal shielding, etc. They can also come from outside sources that pass through the receivers's RF stage and mix with the local oscillator, thus producting an I-F signal which will be amplified and detected as though it were a wanted response.

Either way, receiver spurious problems can be difficult to handle. The first step is to determine if it is internally or externally generated. Remove the antenna. Does the spurious diminish or disappear? Next, place a termination of the proper impedance on the receiver input. Has the spurious disappeared, or is it still there? If removing the antenna and/or terminating the receiver input have no effect on the problem, the spurious is internally generated and the receiver itself will need repair, modification, or redesign. Some sources of internal spurious responses are excess local-oscillator injection; higher than necessary crystal current; RF-amplifier stages not properly neutralized; or open bypass capacitors in the RF stage, to name but a few. Utilizing the receiver's service manual, begin by completely re-aligning the receiver, following their step-by-step procedure. If this proves unsuccessful, work at determining the exact internal cause, using normal troubleshooting procedures.

If the spurious response is external in nature, then the obvious solution is to narrow the "receiver's RF window" through the use of external cavities or crystal filters.

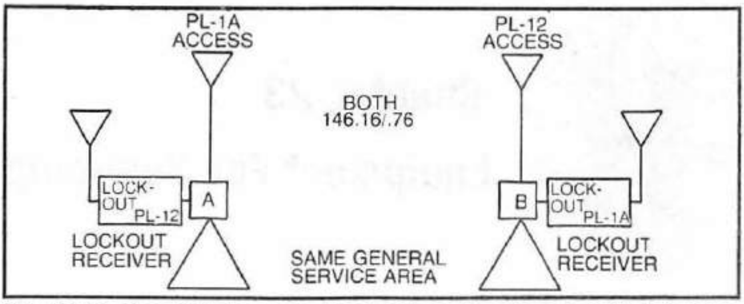


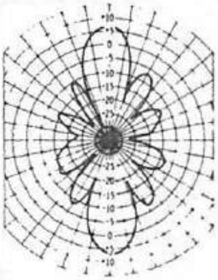
Fig. 22-18. Use of PL tones and lock-out receivers to prevent interference between two repeaters sharing the same frequency and coverage area.

In dealing with spurious responses, it is important to remember that there must be a direct mathematical relationship to either the frequency of the receiver's local oscillator or I-F frequencies. Therefore, shifting either will place the unwanted signal outside the desired passband—this is another possible cure. One way of curing a receiver spurious response is to change the receiver local-oscillator injection frequency from high to low, or vice versa; whichever is the opposite of what is now the injection format. For example, most "import" radios have a first I-F of 10.7 MHz and a second I-F of 455 kHz. This means that the second conversion Local Oscillator injection frequency can be either 10.245 MHz (high IF - 455 kHz) or 11.155 MHz (high IF + 455 kHz). Simply reversing LO injection and retuning the LO chain can eliminate a problem, since one of the constants causing the problem is no longer the same.

Transmitter Spurious Radiations

Spurious signals can be generated by any transmitter, even the best of the "commercial land-mobile breed." They can be caused by inadequate filtering of the final RF output, improper neutralization of the final amplifier or driver, poor transmitter design, and a myriad of other things. You will note that, in this book, there are no new transmitter designs. Rather, we suggest that commercially available equipment—either surplus land-mobile or equipment built for the Amateur marketplace be converted for repeater transmitter service. This is because the FCC recently set some rather tight specifications dealing with spurious radiation emanating from equipment used in the Amateur service, and it is likely that in the coming years, as more spectral crowding takes place, that these specifications will become even more rigid.

Being a "good neighbor" means no radiating spurious signals from your system transmitter(s). Never "short out" a transmitter's output filter to increase power. True, your power meter may increase its reading, however, this is due to reading the total power on all frequencies now eminating from the radio—much of it may now be spurious emissions. If you develop a spurious emission problem, take the offending transmitter out of service at once and repair it. Be sure it is operating properly before returning it to normal service. Additional output filtering may be needed, and cavity resonators designed for transmitter service will attenuate the spurious problem.



Chapter 23

Equipment For Servicing

When you take upon your shoulders the responsibility of repeater operation, you also take on the job of keeping it running properly and legally. This may require that you become familiar with a number of pieces of test equipment that you may never have heard of before. I am not saying that you should go out and purchase everything listed herein. A number of the pieces such as "Service Monitors" and "Spectrum Analyzers" run into the multikilobuck range, and few Amateurs can afford such luxuries. Nor, due to their cost, is it recommended that you take on the responsibility of borrowing such from a "friend" in the two-way service field. Rather, when Spectrum Analyzers or Service Monitors are needed, you should either hire a company so equipped to provide that particular service, or rent the equipment from some organization specializing in rentals.

SPECTRUM ANALYZER:

A device that gives its user a visual display of a selected band of frequencies, and signals present in it. Such an instrument is excellent for determining if a transmitter is radiating spurious signals and for determining the level of its harmonic output. Tuning a transmitter with aid of an analyzer will ensure that the output is exactly where you want it and that both harmonic content and spurious radiations are minimized or eliminated.

SERVICE MONITOR:

Possibly the most useful all-around piece of equipment in a two-way service ship. This high-priced gem can act as an accurate signal source during alignment procedures, gives visual frequency and deviation indications, and a myriad of other functions. Most such units feature high input-sensitivity through use of plug-in modular preamplifiers. This makes a Service Monitor the ideal tool in dealing with situations of radio-frequency interference.

FREQUENCY COUNTER:

A piece of equipment designed to indicate the frequency of any signal applied to its input. Once an extremely costly device, today's technology has brought such devices into a category that almost any Amateur can afford. Recommended is any counter with an upper frequency limit of 500 to 700 MHz and temperature-controlled time-base such as TCXO or Proportional Oven. See Fig. 23-1.

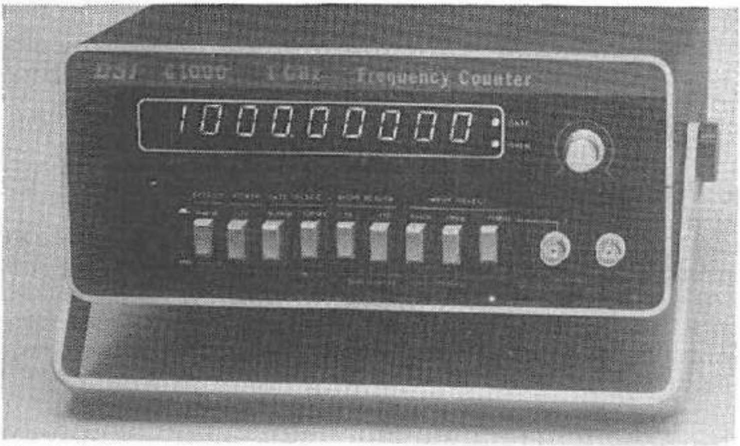


Fig. 23-1. Frequency counters were once a luxury, but now almost any amateur can afford one.

PRESCALER:

Some frequency counters may not have a high enough upper-frequency limit. This can be extended by use of a device known as a prescaler inserted ahead of the counter. A prescaler is an instrument which samples the specific frequency and then devides it mathematically so as to provide output in the range of the counter in direct proportion to the RF being sampled.

RF SIGNAL GENERATOR:

Signal generators used in communications work must feature extreme accuracy, a high order of stability, and an internal attenuator of high calibration accuracy. Many new generators are synthesized units, and meet this exacting set of standards.

STEP ATTENUATOR:

A must in determining the source and cause of interference problems, this device is a calibrated resistive network encased in an RF-tight container, with switches that permit you to select the level of attenuation.

MULTI-METER, VOM OR VTVM:

Used for various checks during normal troubleshooting and tune-up procedures. A minimum sensitiviity of 20,000 ohms per volt is recommended. Note: Meters featuring solid-state amplifiers should be avoided in strong RF environments, if such meters are housed in unshielded cases. Such devices may be prone to pickup from RF fields thus rendering their readings useless. If in doubt, place the meter near an operating transmitter and note any change in meter deflection. If any occurs, do not use that meter in an RF environment. See Fig. 23-2.

DUMMY LOAD:

A 50 ohm dummy load, used for transmitter tests and tune-up.

50-OHM TERMINATION:

Resistive network placed across receiver input terminals to simulate proper antenna impedance. Used during RFI search, and alignment procedure.

ISOLATED TEE FITTING:

Used to introduce a signal into an RF-carrying line for test purposes. Use of an air-gap in the device isolates the introduced RF from the line proper.

Not every instrument listed is needed by each Amateur to keep his radio or relay system operational. However, if one is heavily involved in repeater communications, he should have a working knowledge of each. When the day comes that he must perform maintenance on his system, having this knowledge will make his task a whole lot easier. In fact, he may not be able to perform the required maintenance without the aid of some of this equipment.

A SIMPLE DEVIATION SCOPE

Commercial deviation scopes cost a lot of money, and work very well. The following is a description of one that will work, perhaps not as well, or with as much flexibility, but it will work.

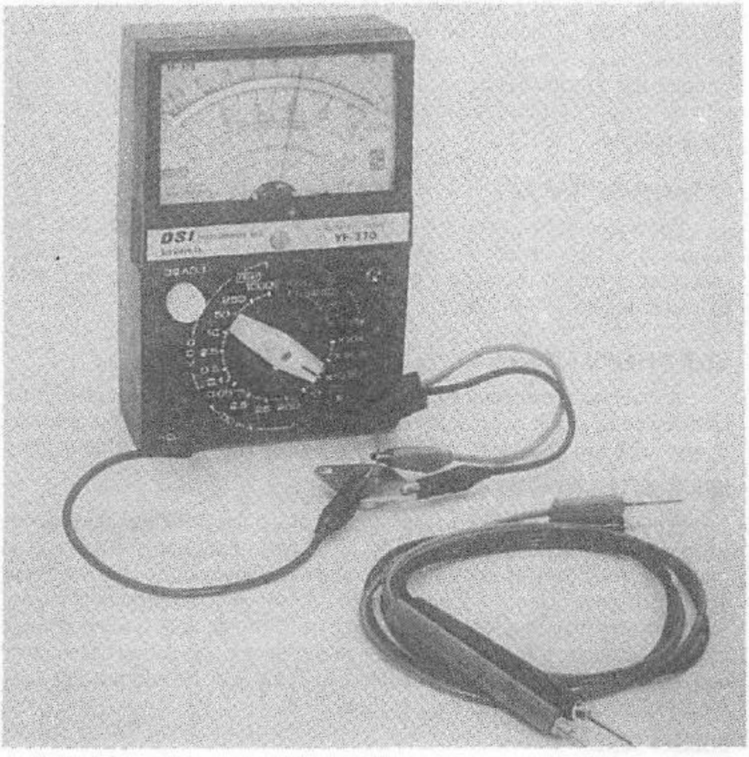


Fig. 23-2. One instrument is a must—the multimeter.

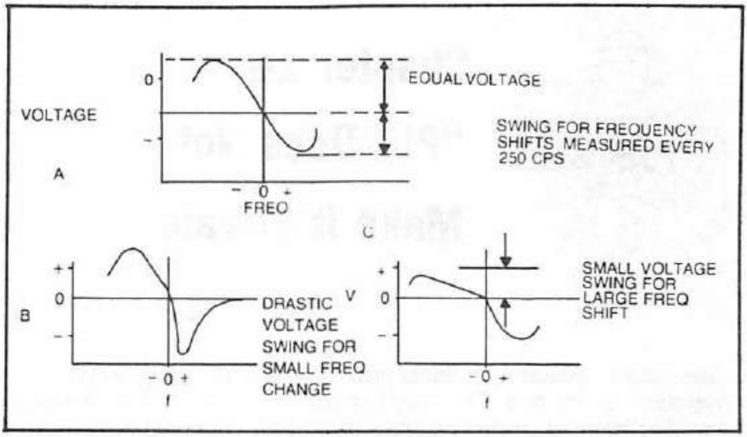


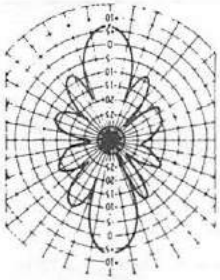
Fig. 23-3. Discriminator DC output curve for a linear system, A, and nonlinear or distorted response at B and C.

One reason that commercial units cost so much is that they cover a wide range of frequencies—the one here covers only those for which you have receiving ability. If you have a synthesized radio you have it made.

Calibration is going to require a frequency counter, and a synthesized radio will make it a lot easier. Linearity, and accuracy will be as good as the discriminator in the receiver.

The basic principle is that the DC output voltage of the discriminator depends upon the received frequency shift, which is the modulation deviation. A DC-coupled scope is connected to the discriminator directly (not to a test point which *may* have filtering between it and the discriminator), and set up to give an indication of modulation when a signal is received. The transmitter is then shifted up in frequency by 5.00 kHz (here's where the synthesized radio takes the work out of it) using the counter for indication. The vertical attenuator of the scope is then adjusted to give an indication of 5 divisions on the scope. The transmitter frequency is then adjusted downwards to 5 kHz below center frequency, and the process repeated. If the scope did not show equal voltage shifts up and down for equal frequency shifts, then the discriminator is non-linear, and it's time for a full alignment. (Note- the radio was built with 10 % components - don't expect extreme accuracy, just reasonably linear. If you want to, make a graph and check the linearity. It should look like Fig. 23-3A. Figures 23-3B and 23-3C show the result if the discriminator is nonlinear or there is distortion or misalignment in the I-F chain.

Don't worry if your radio puts out a positive voltage for negative frequency shift. That was a choice made when the discriminator was designed, and does not affect the operation of this circuit at all. Once you have a fairly linear voltage vs frequency swing displayed on your scope, and with your transmitter frequency back at center channel, you can look at the deviation on your scope, with confidence that you can watch modulation down to dc, it is not dependent on modulation frequency (it's off the detector-before any audio processing), and it is linear and telling the truth.



Chapter 24

"PL" Does Not Make It Private

Many times, we hams get things mixed up. Take tone-access systems on repeaters for example. The many forms of tone access devices developed over the years were never meant to make a frequency or system exclusive to a few Amateurs. Quite the contrary. Tone access was developed to permit more efficient channel sharing between all users. Somehow, to Amateurs, tone access—and one particular form of it, have come to mean "Private—Keep Off." I speak of CTCS.

CTCS

CTCS stands for Continious-Tone Coded Squelch. Though many manufacturers of land mobile FM equipment have such a system available for use with their respective products, one particular trade name has become a part of virtually every Amateur's vocabulary—"PL." The two letters are an abbreviation for "Private Line.*

By whatever name you choose, CTCS is but one of a wide family of tone-access systems. Others are Digital CTCS, Tone-Burst, Dual-Tone, Touch Tone,** and the old stand-by, "Whistle-Up." Of these, only two are really suited for use in today's crowded Amateur bands. They are CTCS in its original form, and its newer digitized cousin. These are "low frequency" systems and do not tend to produce unwanted modulation products in the same manner that "high frequency" systems do. It is for this reason that we will deal mainly with sub-audible CTCS encoding systems in this book. In most Amateur circles, low frequency access systems are quickly replacing high-frequency types. The day of tone-burst and other such systems is fast drawing to a close, except for specialized applications.

Later on, we will be dealing with the technical aspects of CTCS. Exactly how the system works will be explained, and we will offer a number of encoding and decoding schemes. Some you can build yourself and others are commercially available. For the moment, let's evaluate the effect that such devices have had, and are having, on Amateur repeater operation.

TONE ACCESS

Is it tone access that makes a system "closed" or "private" or is it some other parameter? Yes tone access makes it impossible for the

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*"P: and Private Line" are registered trademarks of Motorola Corp.

**-Touchtone is a registered trademark of the Bell Telephone System.

Amateur not so equipped to use such repeaters, but is is the hardware that closes this type of system to most Amateurs, or is it really the attitude of the owner and users of such systems? I contend that it is the latter, and that the hardware acts only to reinforce such policies.

It's a shame that Amateurs are only just beginning to realize what Commercial Land Mobile people have known for years: The real utility of "tone access" is spectrum conservation. As use of land mobile, and associated systems, grew larger and larger, it became apparent that not everyone could have their own private frequency. The spectrum was getting overcrowded, and something had to be done to alieviate such conditions. Users were piled atop one another, and forced to share a single frequency or time share on a repeater. Many objected to the never ending chatter pouring forth from the speaker. It was distracting to some and intolerable to many others.

To eliminate much of this, a number of circuits were designed that would permit a specific transmitter to tell a specific receiver to listen to it. Such systems quickly became quickly very popular. A business now only had to listen to its own people. The delivery man no longer had to listen to the trucking company, and the trucking company was no longer bothered by the construction crews, all of whom shared the same channel. To initiate a call was simply a matter of defeating the tone decoder and monitoring the channel for traffic. If none was present you made your call. If the frequency was in use, you waited until it was clear. Simple and effective.

Many commercial repeaters became equipped with "community Tone Access;" devices that would recognize and relay assigned system users while rejecting all other signals. The repeater would automatically screen all incoming calls, look for the ones containing the proper access tones, and pass both the intelligence and the tone through the system. By passing the specific tone; or in some cases regenerating it at the repeater, the concept of activating only the receiver for which the call was intended was retained. Most of today's commercial-service repeaters use this system, thus permitting many times the spectrum usership that would be possible otherwise.

Another reason for tone access is reduction of interference. Tone access prevents random system key-ups from atmospheric and man-made interference sources. Our electromagnetic spectrum is filled to the "rafters" with all types of RF sources. With millions of transmitters in use every day, it is not inconveivible that now and again a certain percentage of these will fail in some way or another. One way in which failures can occur is a transmitter generating unwanted or spurious emissions. The FCC frowns on such happenings, but nevertheless they do occur, and it may be some time before the person responsible for the operation of the transmitter is notified of the problem.

Right now, let's keep it in the family. Suppose that another amateur system has run amok. It is generating all types of "garbage." If your receiver is carrier access, it will probably be keyed up, and therefore bring your system transmitter into operation. If, on the other hand, your receiver requires tone access, it will just sit there and ignore the whole incident. This does not mean that it will keep your users from being interfered with once they try to key up the system. Only signals strong enough to capture and quiet the receiver will preclude this. It will, however, keep such stray signals from ker-chunking the system and driving everyone up the wall.

Another very annoying source of interference is radar. This type of signal bothers mostly systems operating above 220 MHz, and sounds like a buzz-saw. This problem is highly prevalent in coastal areas and other places where there is an abundance maritime traffic. Here again, tone access is useful, though not a cure-all. It will keep you from having to listen to a constant racket, but will not make the problem go away. Again, only strong signals will overide and, in this case the pulsed nature of the interference makes it all the more difficult to deal with.

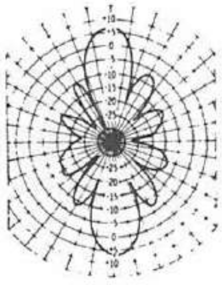
The final source of possible interference we will discuss is that which is caused by other systems sharing the same channel. In some places like Southern California, the number of repeaters and other relay devices coming on the air has far exceeded anyone's estimates. This holds especially true on the two-meter sub-bands. Both are quite crowded, and each month the coordination council receives a number of requests for still more wishing to use part of the spectrum. When you are totally out of channel pairs, where do you put people? There is only one answer: You stack them on top of each other, and force them to time-share as is done in commercial service. There is no other alternative. Use of tone access is one way of minimizing the co-channel interference. The users of repeater "A" will not key up repeater "B" and vice-versa. Today, all two-meter coordinations made in Southern California are assigned not only a channel pair, but an optional CTCS access-tone as well.

They are informed that this is the only way in which they can be granted a frequency, and that should a co-channel or adjacent-channel interference problem arise, the use of tone access will go a long way in making the situation livable, and assuring the survival of their repeater.

These CTCS tone assignments are not haphazard in nature. They follow an area-wide plan adopted by the council's technical committee, and are today applied equally to open, closed, and private category systems. Tone-access codes are published for all open systems so that users wishing to use these repeaters can procure the necessary encoding devices. The plan uses the most common CTCS frequencies, and adheres to the EIA Standardized CTCS Chart. Nor is the use of tone access forced upon any system owner who does not wish to use it. It is an option left open to them, and the only request is that should they elect to initiate tone-coded access on their system, that they use the assigned tone. This is for the sake of standardization and minimal cost to potential users. Obviously, not all systems will ever go to tone access. However, the open systems which have are reporting a high degree of success in minimizing both on-channel and adjacent-channel interference problems, thereby making conditions better for their users.

Along these lines, on bands such as 10 meters and 6 meters, where "skip" is a problem at certain times of the year, the use of tone access becomes almost mandatory unless one of the purposes of your system is DXing or DX monitoring. Don't laugh. Some systems exist for this very purpose, and such operation is quite valid. On the other hand, if you want only local access to your system at all times, then you are left no alternative but to use some form of tone access. This will preclude random keyups by out-of-area signals during times of extended propagation.

Like everything else, tone access has its place. It is a very important tool in the overall development of relay communication, and should be looked at in that light. It is a problem-solver, though not an ultimate solution, and one that must never be feared as being a force which closes doors. Tone access does not make a system or channel sacred. It should not be looked upon, or used, as a "Do Not Enter" sign. It was never designed to be that.



Chapter 25

Why "PL" ?

"PL" or CTCS is not the only tone-access system available these days. We have already listed others that perform the same task, and have yet to discuss "Touch-Tone". Doesn't Touch Tone give you the greatest degree of tone control over your system? Do not other systems decode faster? What is the big advantage of CTCS over the other systems?

CTCS ADVANTAGES

There are many advantages, but the most evident is that, properly installed and maintained, CTCS is virtually inaudible. Note that I said properly installed and maintained. It is very annoying to listen to a signal that sounds as if the filter section of the power supply has gone west. Yet, I operate two radios which perform flawlessly without that telltale hum. There is no real secret other than proper installation and maintenance.

Why use CTCS? We have already mentioned modulation products. Regardless of how clean an FM transmitter is, all FM transmitters do produce sideband energy, which, unlike AM, observe few limitations. Luckily, the overall energy level dissipates quickly with bandwidth. For those who are interested in the mathematics, the following formula is used to define this bandwidth. It is known as "Carson's Rule," and operates as follows:

$B_+ = 2\,(F/W + 1)\,W = 2F + 2W$
F = Modulating Frequency
W = Deviation.

If you consult the appendices, the paper titled "15-kHz Repeater Spacing" by Bob Thornburg, WB6JPI, contains a proper representation of how such calculations are done, and is very explanatory of this topic.

What Carson's Rule proves is that higher modulating frequencies produce higher-energy sidebands, which take greater bandwidth to dissipate. Admittedly, this is an oversimplification, but it will give you a basic understanding of why low-frequency signaling systems are preferable in crowded bands. On two meters, in areas that use 15-kHz channel spacing, it is really the only logical choice. Call it a "Good neighbor policy".

If all this sounds good, it is not without a few drawbacks. First, CTCS decodes relatively slowly in relation to higher-frequency systems. For example, it is possible to decode a 2.5 kHz tone in 35 to 40 milliseconds, while the average CTCS decode time will range from 0.5 second for the lowest tones to 0.2 second for the higher ones. Exact decode time depends upon the specific tone you choose. The simple rule of thumb is the higher the tone utilized, the quicker the decoder response time. Therefore, if your system uses conventional CTCS, it is advisable to educate your users to wait about a half second after squeezing the PTT button before talking. Otherwise, the first few syllables might be lost. There is a way to speed up operation on systems using CTCS access, and this will be discussed later on. It's a system Amateurs have dubbed "Smart CTCS."

The second problem is also one of the CTCS system's greatest attributes. That of it being a continuous, rather than instantaneous access system. Let us compare it for a moment with tone-burst. The latter is a very short-duration pulse sent by a transmitter automatically at the start of each transmision. Burst frequencies center around 2500 Hz, and therefore decode quite quickly. However,once decoded to allow the system to transmit, there is no longer any access security until such time as the decoding logic sees the need for another tone burst. This usually occurs when either the repeaters's transmitter shuts down after a given QSO, or on user-transmission dropout. If, during the transmission by any given user, a stronger station appears on channel and captures the receiver at the repeater, then he can hold that receiver till such time as the system either times out of its own accord or is commanded to do so through its control system. If the reason that your system uses tone access is to prevent some sort of malicious interference, then you have lost to the jammer completely.

Let us apply the same problem to a repeater with CTCS access. As stated, CTCS is a continuous sytem. From the beginning to the end of each user transmission, the receiver/decoder combination at the repeater must see the proper CTCS tone to enable system operation. Should our jammer show up on this system and capture its receiver, the decoder will no longer see the necessary signaling tone, and the system will simply shut down. Here the malicious interference source will not totally win. True, he may have the ability to capture the repeater proper, but he has no audience to listen to his rhetoric. Most jammers tire quickly without ongoing feedback, and soon disappear.

While curtailment of malicious interference is one valid reason to use this form of tone access, it is not the only one. In most cases, tone access is used to prevent random or unnecessary system keyups, and is especially useful where two or more repeaters are co-channeled with some overlap in usership and coverage. Here, CTCS can be used in a number of different ways. It can be used conventionally where the users of each system install encoders for the machine they wish to operate. In such cases, the users of machine "A" will not bring up machine "B". However, the reverse of this can also be a method to exclude unwanted signals without limiting access to the system. One might call it "Reverse CTCS" wherein it is the users who install decoders, and the repeater generates the CTCS tone each time it transmits. Here, the users need not listen to all the chatter, yet they would hear the traffic on the system they elect to monitor.

I stated that the continuous-tone nature of CTCS could be as much of a liability as an asset. Let me explain. Regardless of the type of tone-signaling system used, there is a requirement for high-accuracy in the frequency of the tone itself, and equal stability of the encoder/decoder units. This is to provide proper user recognition while rejecting all other signals. Years ago, this meant some rather complex engineering. However, today's linear, solid-state technology has changed this. Early CTCS encoders relied on mechanically vibrating reeds which were engineered to produce specific frequencies when electro-mechanically activated. The red might best be termed as an electrical generator wherein the impulses it created were amplified and applied to the transmitter's modulator. At the receiver this tone was picked off, amplified again and sent to another reed. This one acted as an electro-mechanical detector wherein it would vibrate in unison with the incoming tone, and this mechanical vibration was used to open the squelch. In a repeater, the opening of squelch also indicates transmit mode under normal operating conditions.

Nowadays, there are electronic devices to replace the vibrating reed type of encoder/decoder. Let's look at two typical encoders and see how this is accomplished. The first method is to use some form of highly stable oscillator, and there are many variations on this theme. Probably the most popular circuit is the venerable "Twin-T" oscillator as depicted in Fig. 25-1. By its very nature, a "Twin-T" oscillator is inherently stable as long as high-quality components are used in the frequency-determining circuit. Even with the highest-quality components you can procure, this is still a free-running oscillator circuit, and therefore will eventually shift in frequency if only due to component aging. After initial burn-in, this circuit will have high stability over long time periods, and will operate well under a wide variation in ambient temperature. This is extremely important in mobile environments where such wide temperature variations are likely to occur often. A complete "Twin-T" CTCS encoder appears in the construction portion of this book. This design, and variations incorporating phase-locked principles, have been used in several commercially produces encoders over the years.

COMMUNICATIONS SPECIALISTS ME-3

Another approach is that taken by Communcations Specialists in their model ME-3 CTCS encoder. Here, a piezo-electric ceramic element replaces the vibrating reed, and digital counting is used to reach the desired tone frequency. The piezo-electric element actually functions in a method similar to the vibrating reed, but in the hundreds of range. It, too, oscillates at an accurate, pre-determined rate and is therefore quite reliable as a frequency-determining element for CTCS tone .

Regardless of the method used to generate the CTCS tone, long-term overall stability is by far the most important criteria that must be considered in this system. This can be further subdivided to long-term transmission stability; ie, holding accurate frequency for the length of a transmission, and overall stability in relation to the number of years of use. There is one more reason to consider CTCS as the logical form of tone access system for Amateur repeaters. It is the very same reason for its popularity in other services: Properly installed, CTCS is almost inaudible! Many of you might take issue with this statement, based upon having heard stations thus equipped humming away wherever they go. The fact is that they need not "hum," as evidenced by my own station equipment. On 220 MHz, I use two systems which are CTCS access. On neither one is my CTCS tone more

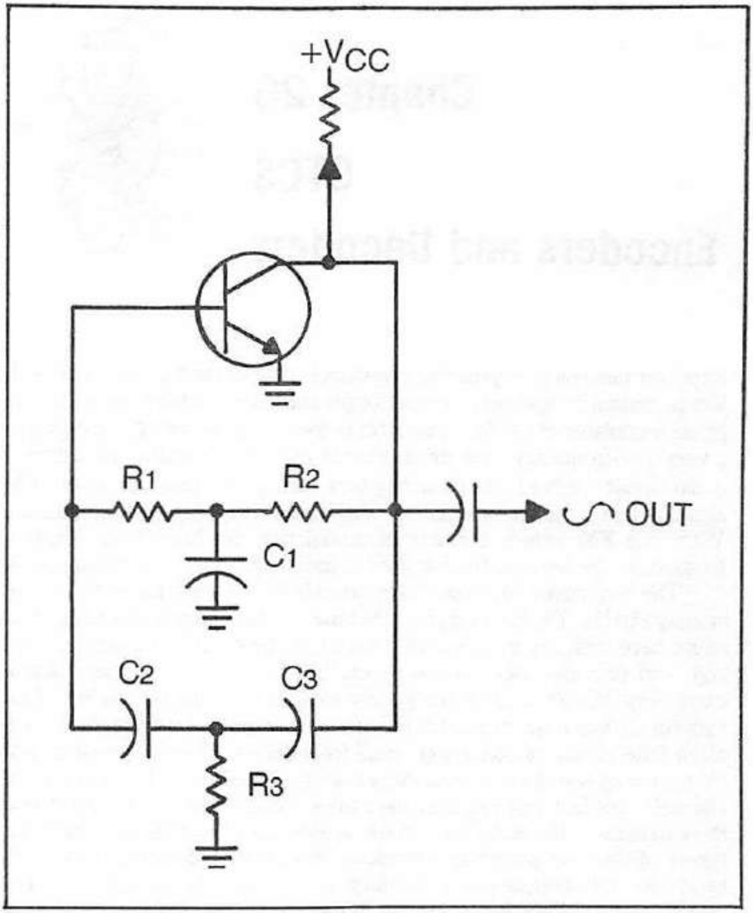


Fig. 25-1. Basic, solid-state Twin-T oscillator for CTCS.

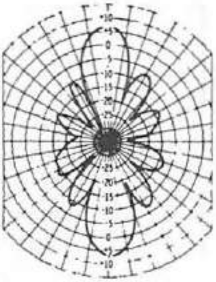
than barely preceptible, yet I am able to access both systems without any problem. This is true of all users on both systems. Also, both systems were engineered to pass CTCS.

On the other hand, high-frequency signaling tones can be quite annoying. They are not as easy to attenuate or filter, and a constant "being" at the beginning of each transmission can drive you bananas after a while. Also, a good number of relay systems use similar tones to signify that the "timer" has been reset. In such cases, multiple bursts of similar tones can play havoc with day-to-day system operation.

My purpose is not to sell you on CTCS as a way of life for every relay system. Rather, if tone access is needed on your particular system, then this form of it is by far the most logical approach, and offers the best overall security with minimal impact. Used properly, CTCS, and all forms of tone-access are devices that will make life easier.

Chapter 26

CTCS Encoders and Decoders



Repeater designs incorporating continuous-tone control schemes are subject to certain special parameters inapplicable to other tone methods. The phase modulator of a F-M transmitter is frequency-sensitive, for example; a very-low-frequency tone must provide more drive to the transmitter's audio circuits than a high-frequency tone for a given deviation level. (FM, again, refers to phase modulation rather than true frequency modulation. With true FM, which consists of modulating the base basic oscillator frequency, the level of tone applied is independent of tone frequency.)

The continuous-tone spectrum extends from around 65 Hz to approximately 250 Hz. The low end provides tones that are easy to filter but which might have difficulty in sufficiently deviating the control transmitter. The high end provides easy-to-use tones, but they are in a range that is extremely difficult to filter adequately without affecting the quality of the audio in the voice spectrum. On the crowded commercial channels there is often little choice of continuous-tone frequencies. Users sharing a radio channel must select a tone frequency that is not being used by others on the channel. This fact may require a user to establish his tone system at one of the extremes— the high end or the low. For this reason, several manufacturers of tone equipment also produce "frequency-modulator" kits to extend the low-frequency capability of the user's equipment. The frequency-modulator kit is nothing more than a varactor device which is placed in the transmitter crystal circuit . After installation, the tone is applied to the oscillator so that the end signal will be frequency-modulated with tone, even though phase-modulated with speech. The most satisfactory approach in the amateur spectrum is to select a tone frequency that is high enough to drive the phase modulator adequately without distortion, yet low enough to allow easy filtering, usually somewhere near the center of the continuous-tone spectrum (between 100 and 160 Hz).

Most amateur systems adhere to the narrowband (± 5kHz) deviation standard. A satisfactory CTS level would be one with a nominal 500Hz tone deviation, with 750 Hz as an absolute maximum.

Filtering the CTS tone from the incoming signal so that it will not be retransmitted enhances the security of a repeater, and it also keep the output channel free of the CTS often-objectionable hum. The simplicity and effectiveness of a tone-elimination filter combine to make its use a virtual necessity in any CTS installation. It is true that some filtering (6 to 8 dB) can be achieved by modification of the receiver de-emphasis characteristics.

But the probability of voice-quality degradation tends to make filter installation a more attractive approach.

Use of the CTS filter on a receiver tends to improve the intelligible-audio recovery (and) hence, the signal-to-noise ratio) to the extent that often the result is an effective increase in receiver sensitivity.

The CTS filter should be installed in one of the receiver early audio stages, such as between the volume control and the first audio amplifier. The important thing to remember is to process the tone from the discriminator for use in the decoder before it arrives at the tone filter.

SIMPLE ENCODERS & DECODERS

The CTCS encoder shown in Fig. 26-1 can be built for a very small investment, and offers a high degree of long-term stability if high quality components are used. It consists of a Darlington transistor connected as a Twin-T oscillator, and an isolation amplifier to minimize loading on the oscillator. The entire decoder can be assembled on a 1-1/2"X 1-1/2" piece of perforated board. The design is simple and straightforward. Q1 functions as a Twin-T oscillator with R1, R2, R3, and C1, C2, and C3 as its frequency-determining elements. R3 is made variable so as to permit adjustment of the oscillator's operating frequency. It is recommended that a 10-or 20-turn trimming potentiometer be used for R3 for ease in final adjustment. Overall operating range can be adjusted by changing the value of C3. Increasing its value will lower the operating range, while decreasing it will have the opposite effect. With the values specified, a range of about 55 to 400 Hz can be expected, and is typical. A Darlington transistor was chosed for Q1 because such devices offer high gain, and therefore are easier to start oscillating and keep oscillating.

Output from the collector of Q1 is capacitively coupled to the base of Q2. Q2 is a silicon NPN bipolar transistor, and has two functions. Q1 looks upon Q2 as a static load,and therefore better stability can be maintained than if the oscillator were directly connected to the transmitter's modulator stage. Secondly, the excessive gain from Q2 permits us to absorb some of the output from the encoder in a wave-shaping network. The combination

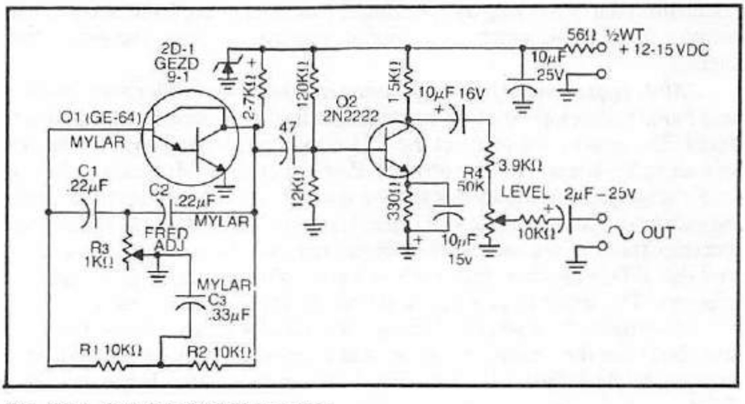


Fig. 26-1. Tunable CTCS Encoder.

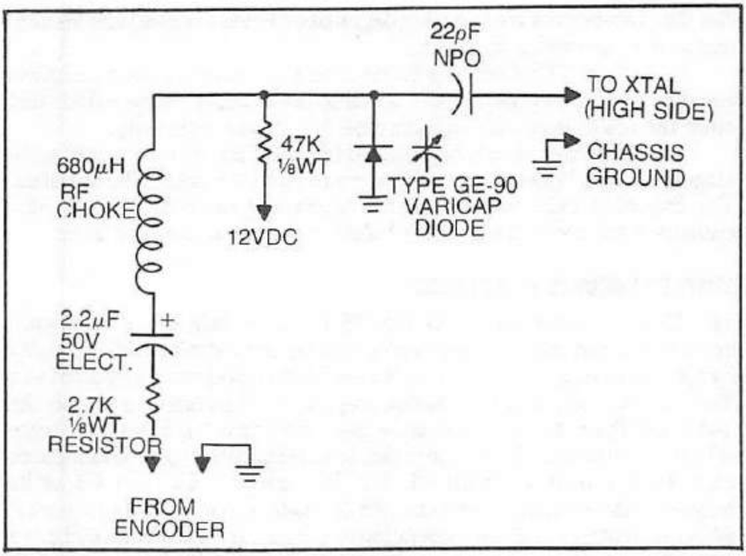


Fig. 26-2. Voltage-variable capacitor (varicap) modulator for use with CTCS encoder.

of C5, C6, and R11 perform this task, producting a near perfect sine wave, free of distortion, and with minimal harmonic content. Components ZD-1, C7, and R8 provide power-supply decoupling and a regulated 9 VDC source for the encoder.

After completion, the encoder should be checked for wiring errors, and, if none are found, it should be connect to a 12-V source and permitted to "burn-in" for about 10 days. During initial testing, an oscilloscope should be connected to the encoder's output, and the waveshape should be observed. You should see a pure sine wave, whose frequency can be varied by adjustment of R3, and whose amplitude can be adjusted by R9. If such a waveshape is not present, then use the oscilloscope to determine if the oscillator itself is working by checking the pattern at the base of Q2 or the emitter of Q1. Use normal servicing procedures to locate the exact difficulty.

After approximately 10 days, assuming that the encoder was checked and found to work properly, you can begin the installation and final adjustment. The exact point to inject the CTCS tone will depend upon the design of your radio. If it is crystal controlled, then either the grid or base of the last audio stage prior to the modulator is a good choice, providing that there is no gain or deviation control at this point. It is important that the level of the encoder tone be set independent of the microphone preamplifier stages, and that CTCS injection take place at a point after any audio processing or clipping. The latter to prevent distortion to the CTCS waveshape.

Alternatively, a simple "Varicap Crystal Modulator" can be built and installed near the channel selector, and coupled directly to the particular crystal for which the CTCS is intended. An example of this is shown in Fig. 26-2.

There is no general rule for injection into synthesized radios, and some experimentation will be necessary. The best place to begin is an audio stage past all clipping, audio-shaping, and audio control. If the connection of the encoder to a given point lowers the overall gain of the audio system in your particular radio, the value of R-10 can be adjusted. Its sole purpose is to isolate the output of the encoder from the audio system in the transmitter. The value specified works well in most radios using bipolar transistor in their audio section. However, a value closer to 150K ohms might be necessary if this encoder is used with tube-type equipment.

There are many ways to adjust operating frequency and deviation level. By far the easiest is by using a combination of a Service Monitor, such as the Cushman CE-3, and a frequency counter capable of accurately reading frequencies between 40 and 330 Hz. The unscaled input port of my DSI Model 3250 suffices for this. The frequency counter can be connected directly across the encoder's output terminals, and R3 should be adjusted slowly until the desired frequency is displayed on the counter. This should be done with R9 set for maximum output. Next, connect the transceiver to a suitable dummy load; couple the service monitor as recommended by the manufacturer, and observe the modulation waveform on the screen. Adjust R9 to the desired deviation level. A quick dab of service cement on both controls to keep them from being changed due to mechanical vibration, and you have completed your installation.

THE WESTLINK TUNABLE CTCS ENCODER

Another tunable CTCS encoder is shown in Fig. 26-3, and is the work of the technical staff of the Westlink Radio Network. Like the previous unit, it uses the time-proven twin-T oscillator design for good overall stability. However, in this design, a pair of type 741 operational amplifier integrated circuits have been substituted for the bipolar transistors Q1 and Q2.

The advantages of the op-amp I/C circuit shown here is that it will produce an even cleaner sine-wave output than is possible using bipolar

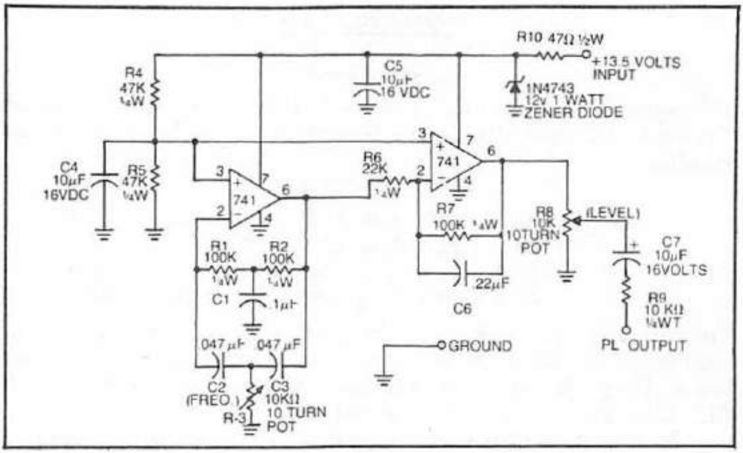


Fig. 26-3. The Westlink CTCS encoder

devices, and the output will be higher. The one drawback to this circuit is that the size of the components makes the completed unit larger.

High-quality components should be used for C1, C2, C3, R1, R2, R3, and as these are the frequency-determining elements. Installation and tuneup are the same as described for the bipolar version.

A DIGITALLY PROGRAMMED MULTI-TONE CTCS ENCODER

The circuit in Fig. 26-4 was contributed by John Portune, WB6ZCT, and was designed and built to fit into a Motorola Motrac, in the location designed to hold the optional factory-installed encoder. This circuit is unusual in that it is a multi-tone unit, and can be expanded to as many tones as is needed. The tone frequency is programmed by diodes, similar to the frequency programming of the ICOM 22S transceiver.

The circuit works by preloading a counter with the number programmed into the diode string (for discussion, this number will be called "I"), counting up until the counter overflows, reloading, and starting over. If the counter is driven by a constant frequency, the rate of "overflows" is proportional to I; the larger the I, the higher the rate of overflows. The circuit takes this overflow rate, divides it by 10, filters it, and uses it, after a stage of amplification as the CTCS output.

A few notes on this circuit:

- 74LS devices are used to cut down power consumption everywhere but in the 7400 1C. This must be a standard 7400 if the oscillator is to work.
- The heavy power-filtering is there for a reason. The designer's application was a high-power radio, with a transistorized inverter to provide high voltage. TTL doesn't like RF or AF noise on its power supply.
- Use a crystal frequency of greater than 1.025 MHz, but less than 2.744 MHz, if you want the full CTCS range of 67.0 to 250.3 Hz.

The programming information is:

$$\frac{(\text{crystal freq.} \div 10)}{\text{CTCS freq. in Hz}} = \text{N}$$

$$4096 - \text{N} = \text{I}$$

I is programmed into the counter, with a diode in place for a zero. Example: Crystal = 2.275833 MHz, tones desired are 107.2, 100.0, 127.3, and 67.0Hz.

Fc ÷ 10 = 227583
227583/107.2 = 2122.9, or 2133 4096 − 2123 = 1973
" /100.0 = 2275.8, or 2276 4096 − 2276 = 1820
" /127.3 = 1787.7, or 1788 4096 − 1788 = 2309
" / 67.0 = 3396.7, or 3397 4096 − 3397 = 699

Convert 1973, 1820, 1787, and 699 to binary, and program the unit by inserting diodes for zeros. A technique for binary conversion is shown below. The programming points in this circuit give counts of 2048, 1024, 512, 256, 128, 64, 32, 16, 8, 4, 2, and 1.

To program an I" count, simply subtract, and note which numbers are subtracted or skipped. For example:

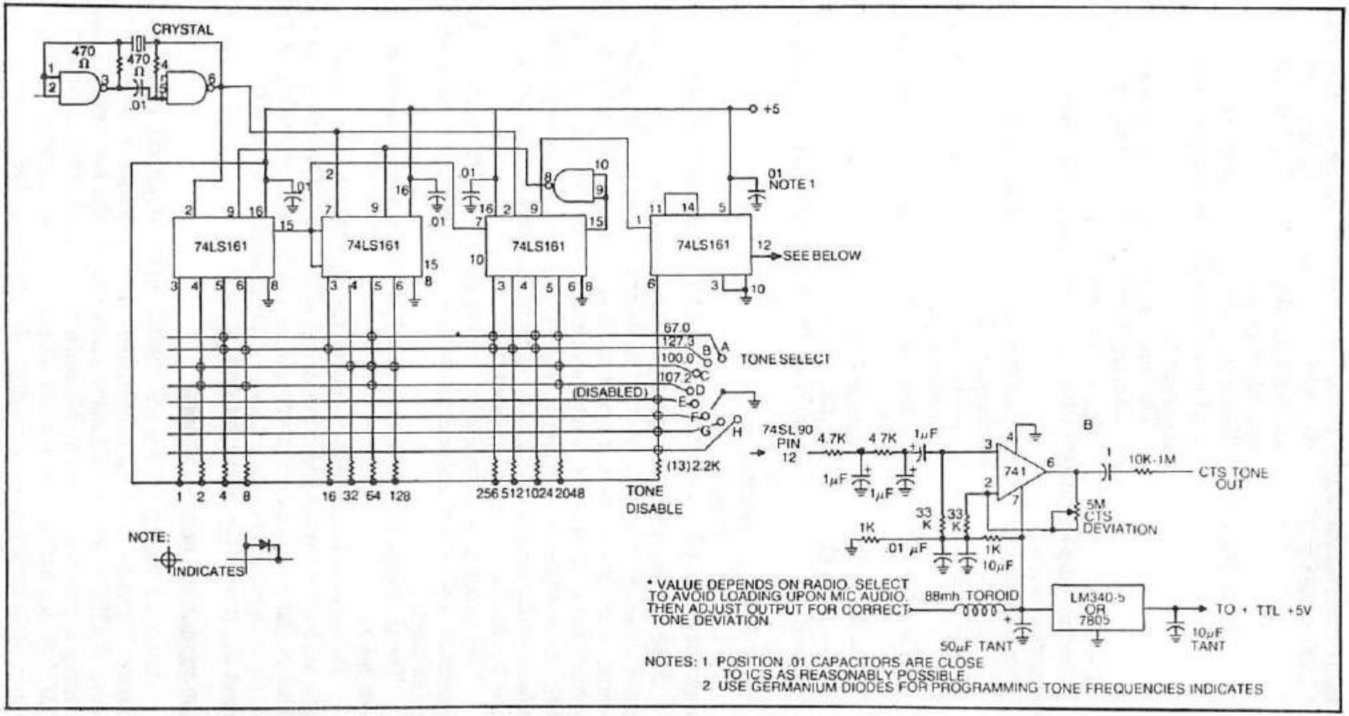


Fig. 26-4. The WB6ZCT multi-tone CTCS encoder.

To figure the programming for 127.3, I = 2309, we would do the following:

2309 – 2048 = 261 We could subtract 2048, so the first number is a 1. We must skip 1024, and 512, so our next two numbers are 0s.

261 – 256 = 5 We can subtract, so the number here is 1. We must skip 128, 64, 32, 16, and 8, so our next 5 numbers are 0s.

5 – 4 = 1 The number here is a 1, since we could subtract. We must skip 2, so here it is a 0.

1 – 1 = 0 The number here is a 1.

Programming is 100100000101, and counting 0s, it will take 8 diodes.

One more example:

For 67.0, I–699 We must skip 2048, and 1024, so our first two numbers are 0s.

699 – 512 = 187 Number is a 1. We must skip 256, so the number is a 0.

187 – 128 = 59 Number is a 1. We must skip 64, so the number is a 0.

59 – 32 = 27 Number is a 1.

27 – 16 = 11 Number is a 1.

11 – 8 = 3 Number is a 1. We must skip 4, so the number is a 0.

3 – 2 = 1 Number is a 1.

1 – 1 = 0 Number is a 1.

Programming for 67.0, I = 699, is 001010111011, and uses 5 diodes.

Note that the programming is crystal dependent, and that the crystal is operating series resonant. Most crystals are cut for parallel, and many oscillate at a slightly different frequency in series mode. The difference is probably too small to notice, but to be on the safe side, build the circuit, and check the oscillator on a frequency counter. Also, when selecting a crystal, make sure that none of the harmonics land on your receiver frequencies, or wire the circuit to be only on when transmitting.

This circuit is a excellent for conversion to CMOS, since its RF resistance, low power, and higher function-count-per-chip characteristics are all needed here.

The prototype in Fig. 26-5 is on a P.C. board, with components on both sides.

The series output resistor is marked at 10k to 1M, because it must be selected for the radio in which this circuit will be used. The idea is that the value of this resistor is high enough so that there is no loading of the microphone audio, but small enough to have little effect on the CTCS level. Inject the tone at the modulator grid, or base.

TWO-FREQUENCY BURST ENCODER

Actually I should call this one the WA2HVK/WA2INM Tone-Burst Encoder, because it was a cooperative effort in design between Larry Levy, WA2INM, and myself many years ago. In the late 1960's I was planning a trip cross country. My radio was a simple two-channel RCA CMCT-60 for 146.34/.94 and .94 simplex. Having heard a number of stories about some repeaters requiring short bursts of high-frequency tone

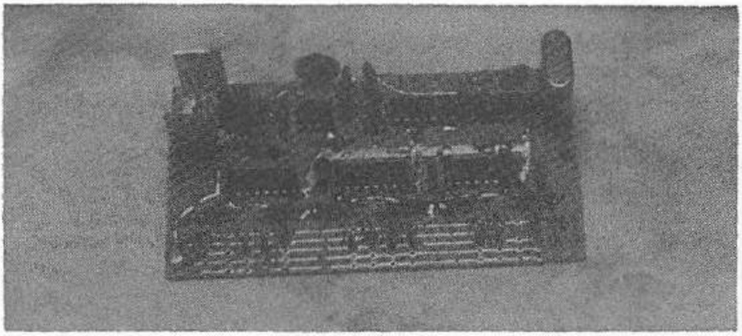


Fig. 26-5. Prototype of the WB6ZCT multi-tone encoder.

to access them, Larry and I spent a sleepless Saturday night developing a small transistorized unit which would permit me to carry at least two of the more popular burst tones; 1700 and 1750 Hz. What you see in Fig. 26-6 is a modernized version of what we produced back then. The main change has been substititution of more modern and commonly available parts for the unidentifiable surplus items used in the original design.

The original unit used Germanium PNP transistors scrounged from a defunct transistor radio. We have modified the circuit to use some general replacement audio transistors manufactured by RCA, see Fig. 26-6. However, any good high-beta transistor of the Silicon NPN variety will sufffice for Q1, and just about any NPN Silicon will suffice in the Q2 position. With the exception of C1, C2, and C3, little else is critical. Again, since these components determine stability under varying termperature conditions, high-quality Mylar capacitors are recommended.

This unit was designed to be preset to any of two discrete tones within a frequency range of 400 to 3000 Hz. A miniature SPST toggle switch is

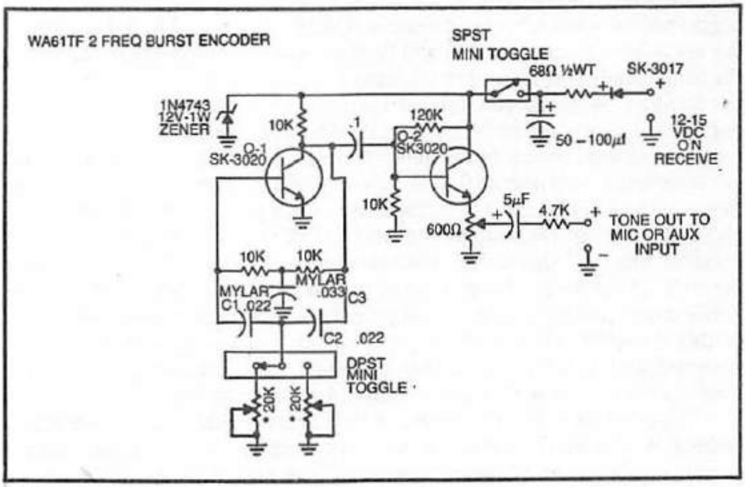


Fig. 26-6. A two-frequency tone-burst encoder.

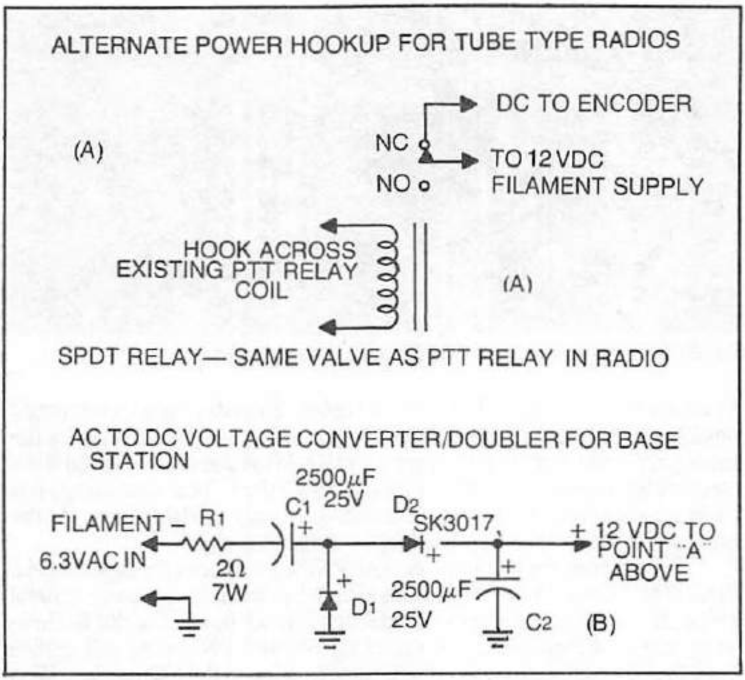


Fig. 26-7. A method of keying the tone from the encoder, A, and a source of 12-V DC from 6.3 V AC filament supply, B.

used to change frequency. If you desire only one frequency, then the switch and one of the 20k trimports, can be deleted and the stator of the remaining trimpot connected directly to the junction of C1 and C2. In my unit, the toggle switch was cemented to one end of the perforated board on which the encoder was constructed, and then mounted through a hole drilled in the front panel of my home-brew control head. A second toggle switch, this one an SPST, is incorporated so as to permit the encoder to be disable when not needed. It is wired in the position shown for one important reason: This particular design uses a rather novel timing scheme for tone duration. In burst systems, only a short 0.25 to 0.5 second tone is required. To achieve this, a 50 to 100 µF electrolytic capacitor is charged from the receiver's B plus supply. When the transmitter is activated, B plus is removed from the receiver line, and this causes the encoder to cease functioning at a rate determined by the discharge time of the 50 - 100 µF capacitor, the 12 V Zener diode, and the resistive load provided by the circuit itself. The value of this capacitor will actually depend on the exact length of burst tone required, and, in some cases, even the 50 µF value may produce to long a tone duration. Adjust its value to suit your particular needs.

A quick look at the remainder of the circuit reveals that we are again looking at a "Twin-T" oscillator, with the component values adjusted to permit oscillation at a higher frequency. The output of this oscillator is capacitively coupled to a second NPN silicon device, which functions as an emitter-follower, affording good isolation between the oscillator and the transmitter's audio section. Injection of the tone to the audio system of the transmitter is not as critical as with CTCS, and any convenient spot will suffice. An excellent choice is directly across the microphone input jack, or to an auxiliary audio-input port that the manufacturer of your radio may have provided. A 600-ohm potentiometer in the emitter of Q2 adjusts output level.

Two very important notes in relation to this encoder. First, it was designed for use in radios which are relay-switched between transmit and receive. Without additional circuitry, it will not function properly in radios, such as the Icom IC-22S, which utilize electronic switching. Do not attempt to use this encoder with such radios unless you can modify them to provide the encoder with 12 VDC during the receiver cycle only. If this precaution is not adhered to, the oscillator will be running constantly, and will act as a continuous-tone unit while transmitting. B plus must be disabled during transmit.

Secondly, if you intend to use this encoder with older tube type equipment, do not connect it directly to the receiver's B-Plus supply, or severe damage will occur to both the encoder and the radio. An alternative, in such cases is to use the filament supply as a source of power. If it is a mobile installation, parallel a small SPDT relay with the PTT relay in the transceiver, and wire the 12 VDC filament supply to the encoder through the normally closed contacts, as shown in Fig. 26-7. In a base-station installation, where the filaments are powered by 6.3 VAC, a simple, half-wave voltage doubler, as shown in Fig. 27-7B will provide the necessary DC potential. Tuneup procedure is the same as with the CTCS encoders previously covered.

ANOTHER FORM OF CONTINUOUS SQUELCH

Many multi-site repeater systems, when they are first built, have a characteristic that their owners don't like—extra squelch tails. Several techniques have been used to eliminate this, but the most commonly used one seems to be "chicken-burst," using the CTS encoder on the link as the indicator that the main channel receiver COR is active.

This is all well and good, and will work, but it introduces a new problem: that of system response-time.

Figure 26-8 shows a typical system with this sequence of events! The user presses his microphone button, and the receiver site(s) COR responds. The down-link transmitter(s) turn on, and 1/5th of a second later, the voter-site CTS decoders unsquelch the receivers. The voter unit keys the up-link transmitter, and 1/5 of a second later, the link receiver decoder keys the system transceiver. Total system response time is 400 mS on a CTS system, 600 mS if the main input receivers are CTS also.

The cure? Several are possible: 1. Run the links on carrier squelch. This is impractical, for system-security reasons, regardless of the fact that radar would destroy a 220, 420, or 440 MHz link, and render the system useless. 2. Use higher frequency CTS tones—in the 200-250 Hz range. These tones decode a bit quicker than the lower-range tones, but would only get the time down to 1/10 to 1/5 second, and would be difficult to filter out of the repeated audio. 3. Replace the CTS tone with an audible tone in

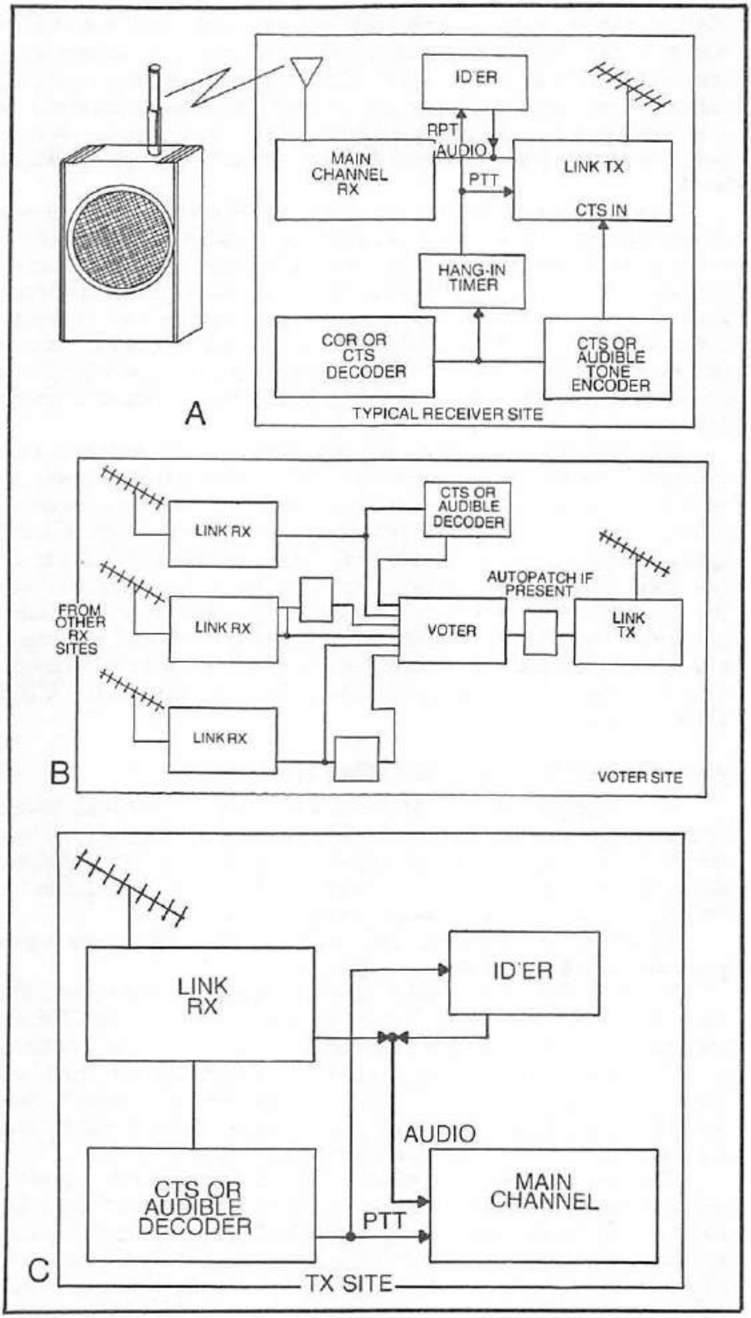


Fig. 26-8. Typical multi-site system.

the 2000 to 2700 Hz range, at about kHz deviation, and then notch it out before the voter circuitry. Reinsert it after the voter, and then notch it out again before the audio gets to the main-channel transmitter. 4. Run CTS on the links if you want to, but ignore the CTS decoder for the first 300 MS. A possible technique is shown in Fig. 26-9.

The advantage of audible tone? It decodes in 50 mS or less. Let's look at our example again. The mobile-to-receive-site time would remain unchanged—zero for a carrier-squelch system, or 1/5 second for a CTS system. The receive-site to voter-site link is now 50 mS (worst case), the voter-site to transceiver is another 50 mS, for a total of 100 mX (carrier squelch) or 300 mS (CTS system), instead of 400 or 600—a distinct improvement. Note that in our discussion we are not considering relay pull-in time, PTT-activation-to-RF-out time, or anything but CTS *vs* audible decode time.

How about notch filters? Won't they ruin the sound of the system? No, not really. If you have narrow, deep notches, you'll be able to talk through them and never know it. As an experiment, 3 notches 45 dB deep , at 1000, 1500, and 2000 Hz and 20 Hz wide were inserted in a link path and the users never knew it. Adequate filters can be made using 88mH RTTY toroids. Touchtone-pad toroids, or adjustable inductors. Frequency stability is important in the encoders, decoders, and filters, so use good quality parts.

There is one technique of obtaining encoder/decoder stability that the author has not seen in any article or book, and that is using pager reeds. The two-tone system of paging is being replaced by the new high-speed 5-tone system in all of the large cities in the nation, and the two-tone pagers and reeds are being sold as surplus. The encoder and decoder design can be "lifted" from any reed type CTS design (a component value or two may have to be changed). Many times, reeds can be purchased for 50 cents to a dollar, and complete, high-band pagers can be purchased for $20. The tone-and-voice models can easily be converted to carrier squelch and used as pocket monitors.

Another possibility is to use a crystal oscillator and divider chain, but be sure to use a filter after it to end up with a sine wave.

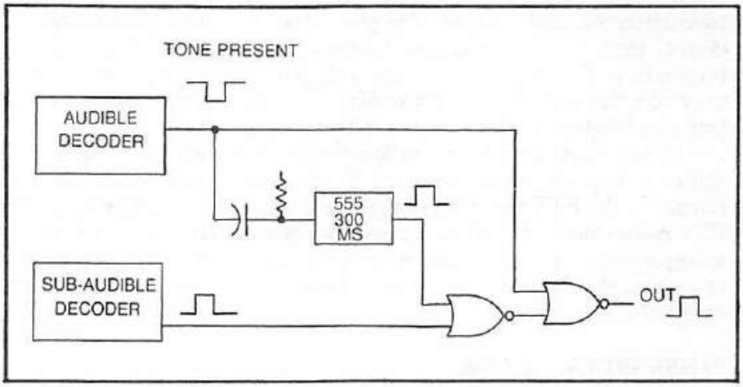


Fig. 26-9. Using a 555 oscillator to simulate a subaudible for the first 300 milliseconds decoder in a two-tone system.

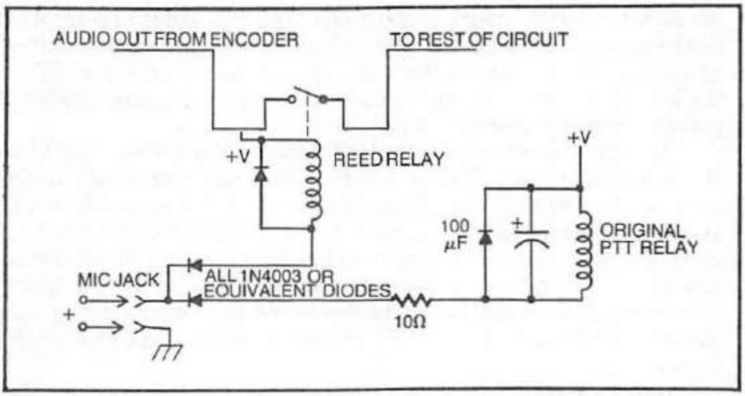


Fig. 26-10. Schematic diagram for an inexpensive "chicken-burst" system.

REVERSE-BURST AND CHICKEN-BURST...WHAT ARE THEY?

When PL was first introduced by Motorola, some smart engineer came up with an interesting technique of eliminating the squelch tail in the receiver. The marketing department thought up the name "Reverse-Burst," told the Legal department to trademark it.

GE and RCA needed an equivalent technique, and the method that they use is sometimes called "Chicken-Burst" by Amateurs.

Motorola's technique is that, when the user releases the microphone button, the phase of the PL tone flips 180 degrees and double the amplitude, which stops the mechanical-decoder reed dead in its tracks. The fact that the reed stops moving closes the CTS squelch. The burst lasts 150 mS from the time the user lets go, and by the time that the carrier drops off, the CTS squelch has shut off the speaker, and the users hear no squelch tail. Note that all of the hardware for this is in the transmitter—all that is needed in the receiver is a mechanical reed decoder.

GE and RCA's technique is a bit different—it had to be to avoid patent problems. In their radios, they simply turn off the one, then drop the transmitter 200-500 mS later. The reed coasts to a stop, the CTS squelch closes, then the carrier drops. Likewise, all the work is done in the transmitter. The advantage of this is that some non-reed decoders can be used with this system and not with Motorola's phase-reversing technique. One disadvantage is that the transmitter hang-in time is a bit longer.

A schematic diagram of an inexpensive "chicken burst" system is shown in Fig. 26-10. In operation, the reed relay drops instantly upon release of the PTT line, removing the PL tone. The capacitor keeps the PTT relay closed for 200 mS or so. The diodes short out any transient spikes from the relay coils, and prevent the capacitor from keeping the reed relay closed. The 10-ohm resistor limits the charging current of the capacitor.

PAGING WITH A CTS TONE

An interesting feature used by some repeaters in the Los Angeles area is slowly growing in popularity, here and across the nation. This idea is to

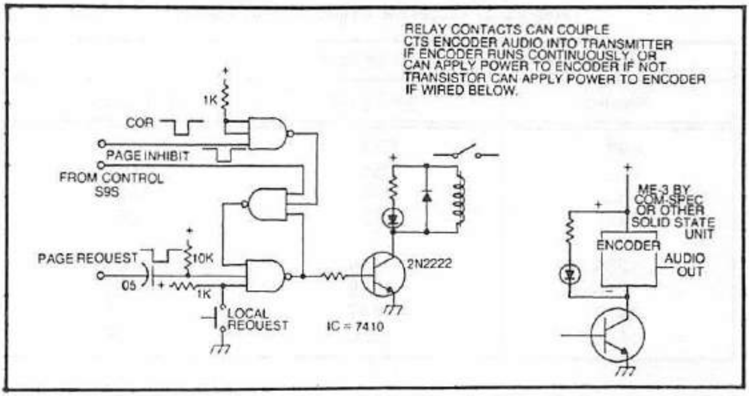

RELAY CONTACTS CAN COUPLE CTS ENCODER AUDIO INTO TRANSMITTER IF ENCODER RUNS CONTINUOUSLY, OR CAN APPLY POWER TO ENCODER IF NOT
TRANSISTOR CAN APPLY POWER TO ENCODER IF WIRED BELOW.
+
1K
COR
PAGE INHIBIT
FROM CONTROL S9S
+
PAGE REQUEST
10K
.05
+
1K
LOCAL REQUEST
IC = 7410
+
2N2222
+
ME-3 BY COM-SPEC OR OTHER SOLID STATE UNIT
+
ENCODER
AUDIO OUT
-

Fig. 26-11. Circuitry for connecting a paging encoder to a repeater transmitter.

Table 26-1. Common and recommended CTS frequencies.

FREQUENCY, Hz	Code		
67.0	XZ	L1	
71.9	XA	L2	
74.4	WA		
77.0	XB	L3	
79.7	SP		
82.5	YZ	L4	
85.4	YA		
88.5	YB	L4A	
91.5	ZZ		
94.8	ZA	L5	
97.4	ZB		
100.0	1Z	1	
103.5	1A		
107.2	1B		
110.9	2Z	2	
114.8	2A		
118.8	2B		
123.0	3Z	3	
127.3	3A		
131.8	3B		
136.5	4Z	4	
141.3	4A		
146.2	4B		
151.4	5Z	5	
156.7	5A		
162.2	5B		
167.9	6Z	6	
173.8	6A		
179.9	6B		
186.2	7Z	7	
192.8	7A		
203.5	7B		M1
210.7	8Z	8	M2
218.1	8A		M3
225.7	8B		M4
233.6	9Z	9	M5
241.8	9A		M6
250.3	9B		M7

Table 26-2. Touchtone frequencies and limits.

#2 Tone limits		
Nominal	**Low Limit**	**High Limit**
697	683	711
770	755	786
852	834	869
941	922	960
1209	1184	1233
1336	1309	1363
1477	1447	1507
1633	1600	1666

decode a 2- or 3-digit Touchtone sequence on the input channel, and turn on a CTS encoder on the output for the duration of the carrier on the input.

The purpose of this equipment, interesting enough, is to get more people to monitor the repeater; people who would otherwise turn off their radios because they don't want to hear all of the "meaningless chatter." The

Table 26-3. Dual-tone frequencies and Telephone Company tones and uses.

Dual-Tone Multi-Frequency signaling (DTMF)
Also known as Touch-Tonetm, or Touch-Calltm

Low Group				Consumer Military
697	1	2	3	A (Fo)
770	4	5	6	B (F)
852	7	8	9	C (I)
941	*	ϕ	#	D (P)
	1209	1336	1477	1633 OPTIONAL

Fo = Flash Override
F = Flash
I = Immediate
P = Priority

Must Decode Bandwidth ± 2%
Must Not Decode Bandwidth: ± 3.5%
Maximum twist (difference between high and low group amplitudes): ± 6 dB
Minimum signal-to-noise ratio: 18 dB
Minimum dial tone rejection: 18 dB
Nominal interdigit time: 40 mS

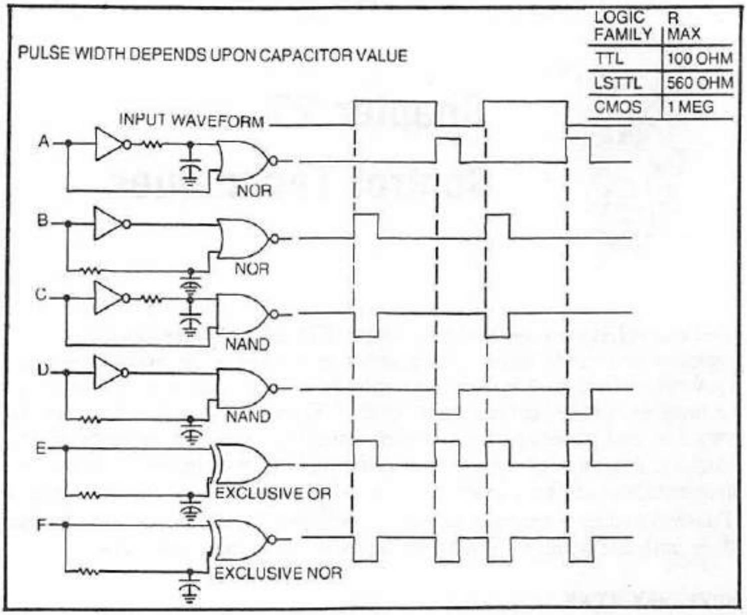
Recommended for radio systems: 50 mS tone duration, 50ms interdigit.

	350 Hz	440 Hz	480 Hz	620 Hz	Cadence	C.O. Level
Dial Tone:	x	xx			continuous	– dBm
Busy			x	x	½ sec on, ½ sec off	–24 dBm
reorder* ('fast busy')			x	xx	0.2 sec on, 0.3 sec off	–24 dBm
ringing		x	x		2 sec on, 4 sec off	–16 dBm
high tone**			xx		varies with use	–16 dBm
premption***		x		x	single 200 to 500 mS pulse	–18 dBm
call-waiting		x			single 500 mS pulse	–13 dBm

ringing voltage applied to instrument: aprox. 105 V 20 Hz.

* frequently used to indicate "all trunks busy."
** used as status tones for operators, or to indicate prolonged off-hook condition to customers.
*** used most frequently in private networks.

These tones and voltages may vary with different telephone companies



LOGIC FAMILY	R MAX
TTL	100 OHM
LSTTL	560 OHM
CMOS	1 MEG

Fig. 26-12. Some handy circuit tricks with gates.

users simply install CTS decoders on their receivers, with the speaker leads run thru the relay contacts. When a carrier with CTS comes on, the speaker turns on.

The circuitry in the repeater is shown in Fig. 26-11. It is basically a R-S flip flop, set by the page request, and cleared by the COR. An extra input is used for a local trigger. An inhibit input is provided for connection to your system-control logic, in case this feature is abused.

The end result of all this is that people can hide behind a CTS decoder, yet anyone can "page"them if they are needed. This is very useful at times, and takes very little hardware, time, and effort.

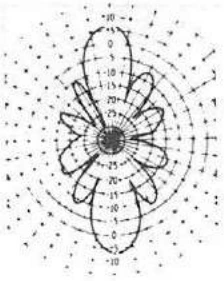
Table 26-1 shows most of the common CTS code frequencies. Nominal deviation for these tones should be 500 Hz, with 750 Hz maximum. Encoding accuracy is ± 0.25 %, and the decode bandwidth is ± 0.5 ±.

Some odd-ball tones that have been found in radios, but are not recommended include: 81, 90, 121.1, 124, 127, 169, 188, 209, 113.2, and all pager reeds from # 101 (202.7 Hz) through # 136 (258.8 Hz).

Table 26-2 shows some common Touchtone frequencies,and their limits under the 2 % rule. Nominal level to the central office decoder is -16 dBm, and the limits at the central office decoder are + 6 to − 26 dBm.

Table 26-3 is a list of dual-tone, multi-frequency, signaling frequencies, and some specifications and timing for tones used in many telephone-company systems.

Some handy circuit tricks that can be used with decoders and control circuits are shown in Fig. 26-12. The last two, E and F, can be used as digital frequency doublers if the R and C values are chosen for 50 % duty cycle.



Chapter 27

Control Techniques

The control system is the heart of any FM or AM relay device, be it a repeater or remote base. This chapter will cover some practical control systems, whether they are currently in wide use or not. All of these techniques simply "extend your hands." They give you the ability to flip switches and push buttons remotely, and they are just as applicable to sprinkler systems, or other as non-radio applications, repeaters. In fact, an acquaintance of the author uses a 10 μV sensitivity receiver and a Touchtone-digit sequence detector (explained later) to open his garage door with a Touchtone-equipped 220 MHz hand-held transceiver.

HOW THEY WORK

Once the command to "flip the switch" has been received, the switch itself has to be flipped. The "switch" takes the form of a logic latch or a latching relay. In fact, up to the latch, the "flip-the switch" and "push-the-button" commands are of the same form, which is a pulse from a digit-sequence detector.

Depending upon the characteristics of your command decoder, this pulse may be anything from microseconds to seconds long. If a relay-type decoder is used, the command latch will probably also be a relay.

If the system is TTL/CMOS based, the latch will probably drive a relay.

Obviously, a simple relay is of itself inadequate; a conventional relay will pull in with an applied pulse, but when the pulse is gone the relay drops out. A latch relay, on the other hand, serves as a bistable multivibrator, or flip-flop; it pulls in and holds when the pulse is applied, and a second pulse is required to release it.

Latch relays can easily be built using standard relays as elements, or they can be purchased as units. Off-the-shelf latch relays take several forms: the magnetic latch, the double-coil, and the ratchet, are but a few. If you build your own, you will probably decide on either the double-relay electrical latch or the self-latching type.

Probably the most expensive (except in surplus) of all the latches is the magnetic type, which typically responds positively and fully to extremely short pulses. A magnetic latching relay with a 2-ampere switching capability may be physically no larger than a small hermetically sealed crystal can. From the standpoint of miniaturization, it is an attractive package.

The relay has two coils. When the "on" coil is energized by a short voltage pulse the contacts are held securely by a magnetic element. (This system provides an additional benefit to the user because of the lack of contact bounce.) It takes a new voltage pulse at the "off" coil to overcome the pull of the magnet and return the relay to the original state (also magnet-held).

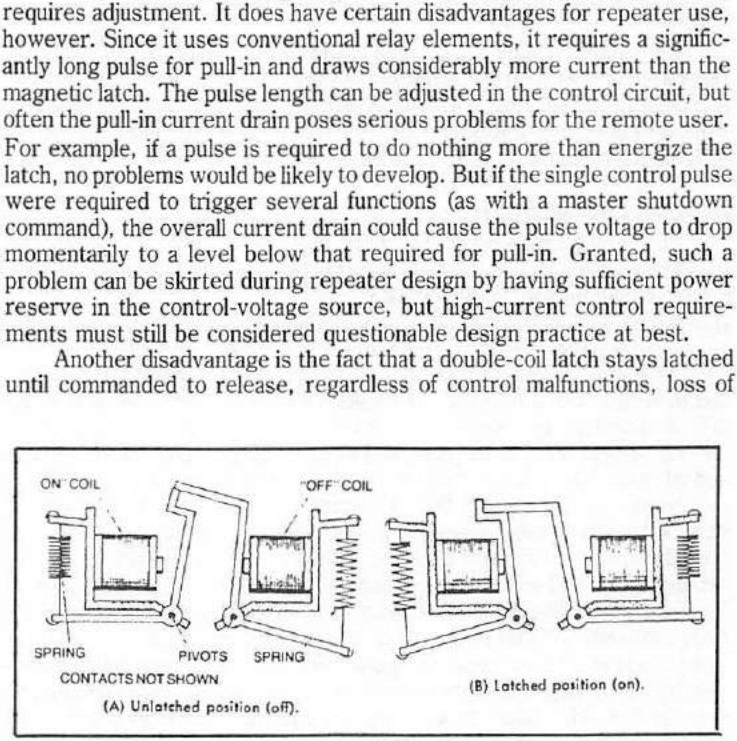
The magnetic latching relays do have disadvantages, however, over and above the high initial cost. They are generally not satisfactory for inductive loads. Also, the contacts must not be used for switching loads higher than rated. A more or less typical problem with magnetic latching relays is a sudden inability of a pulse to cause the relay to change states. In most cases this has proved to be attributable to contact "welding," where an excessive load was switched. Since these relays are hermetically sealed, malfunctions generally make them useless, and impossible to repair.

Another problem inherent with a magnetic latching relay is its inability to return to the "off" state without a positive command. This limits the "fail-safe" features of a remote system. For repeaters and remote-control applications, magnetic latching relays are not recommended.

The double-coil latching system is also often referred to as a mechanical latch. With this approach, two conventional relays are combined in such a configuration that one holds the other in the "make" state, as shown in Fig. 27-1.

This double-coil latching relay is normally of high reliability and rarely requires adjustment. It does have certain disadvantages for repeater use, however. Since it uses conventional relay elements, it requires a significantly long pulse for pull-in and draws considerably more current than the magnetic latch. The pulse length can be adjusted in the control circuit, but often the pull-in current drain poses serious problems for the remote user. For example, if a pulse is required to do nothing more than energize the latch, no problems would be likely to develop. But if the single control pulse were required to trigger several functions (as with a master shutdown command), the overall current drain could cause the pulse voltage to drop momentarily to a level below that required for pull-in. Granted, such a problem can be skirted during repeater design by having sufficient power reserve in the control-voltage source, but high-current control requirements must still be considered questionable design practice at best.

Another disadvantage is the fact that a double-coil latch stays latched until commanded to release, regardless of control malfunctions, loss of



(A) Unlatched position (off).

(B) Latched position (on).

Fig. 27-1. Double-coil latching relay configuration.

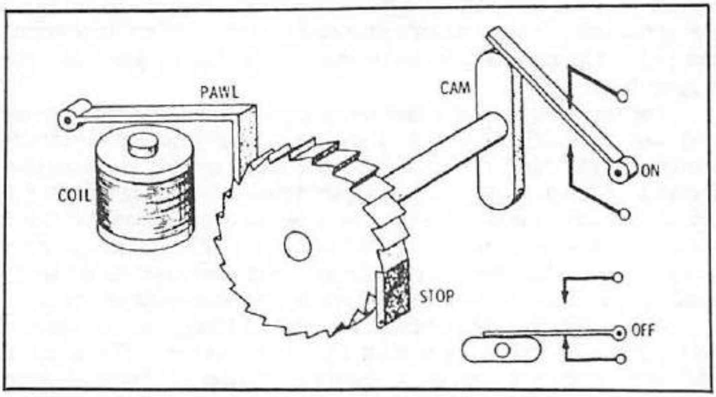


Fig. 27-2. Single-coil ratchet relay.

communication with the repeater, etc. Ideally, momentary power loss or temporary system shutdown should return all latched relays to their original states.

RATCHETS

The ratchet is similar in concept to the double-coil relay, but it incorporates a single coil. The first pulse latches the relay on, the second releases it. The prime disadvantage with this system is that the control operator may wind up energizing a function he wants to shut down. Figure 27-2 is a schematic presentation of the ratchet relay.

Electrical Latching Relays

Electrical latching relays are by far the best for remote use because they allow a wide latitude of built-in safety features, and because they can be easily built up with conventional relays. The simplest electrical type is the self-latching relay. This concept involves the use of an extra set of contacts on the relay for supplying the relay's own coil voltage.

As Fig. 27-3 shows, a simple latch can be built by connecting the relay coil in series with a resistor. The value of the resistor is so chosen that sufficient voltage is developed across the relay to keep it energized. If a 28-volt system is used, the relay coil voltage can generally be between 20 and 24 volts. The resistor itself will be fed the remaining 4 to 8 volts. The resistor should be no less than 10 watts because it will be required to dissipate a considerable amount of power on a surge basis when the relay is pulsed off. As shown, the 28-volt "on" pulse causes the relay to pull in (assuming the coil draws 100 mA and will operate from a 23-volt source). The continuous 28-volt source continues to supply coil voltage through the relay's closed contacts. In the event of a momentary power loss, the relay opens and cannot close again until pulsed on. The "off" command consists of pulsing the ground side of the relay with a pulse of the same polarity as the ungrounded side. When this occurs, no voltage is developed across the relay coil and it opens. As with a power loss, a new "on" pulse is required to engage the relay again.

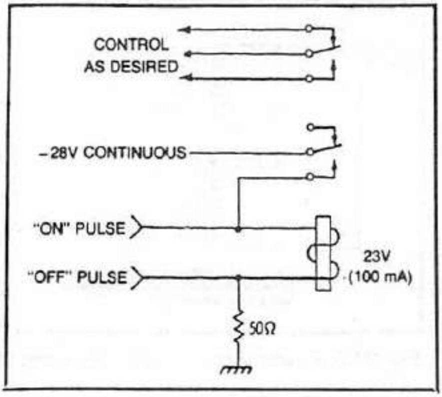


Fig. 27-3. Schematic of a self-latching relay setup.

When the 28-volt pulse is applied to the ground side of the relay, the resistor is required to dissipate the full load, which in the case shown is more than half an ampere, or nearly 12 watts. The 10-watt resistor will easily handle short pulses of up to 20 watts without degradation. The chief disadvantage is the tremendous current surges required of the control-voltage power supply.

The optimum electrical latching relay from a design standpoint is that shown in Fig. 27-4. This approach combines the advantages of the self-latching relay but offers no taxing burdens on the power source. It utilizes two conventional relays for on-off control. The normally closed contacts of the "off" relay carry the primary supply voltage for the latch. When the off relay is pulled in or when power is momentarily lost in the circuit for any reason, all relays return to the normal state. A series diode should be inserted at the point marked "X", to avoid the continuous 28v traveling back on the "on" pulse line, and possibly damaging previous circuitry.

Sooner or later, there comes the question of whether or not to incorporate a separate power supply as a control-voltage source. From the information presented in the preceding pages, you have probably already come to the conclusion that a low-voltage direct-current power source is a hard requirement for control of a repeater or remote station. In truth, such is not necessarily the case. There are no rules specifying the state or polarity of the voltage you use for control of your system; it can be AC or

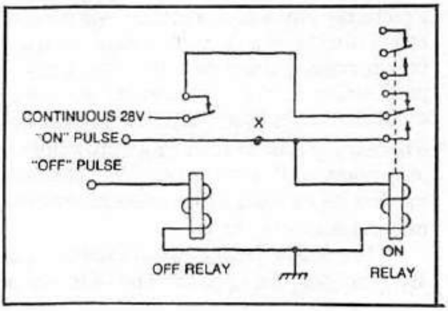


Fig. 27-4. Two-relay electrical latching system.

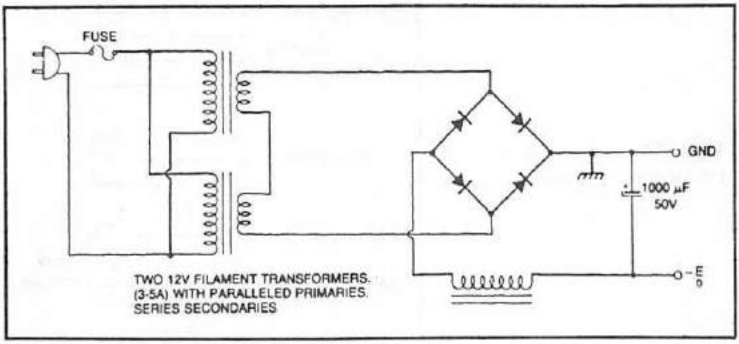

FUSE
GND
1000 µF
50V
$-E_0$
TWO 12V FILAMENT TRANSFORMERS.
(3-5A) WITH PARALLELED PRIMARIES.
SERIES SECONDARIES

Fig. 27-5. Power supply for 28 volts using standard filament transformers.

DC, negative or positive, low voltage or high. But there are a number of tradeoffs to be considered when making the final decision.

Obviously, the simplest idea would be to use the commerical 120-volt AC power right off the line. But the drawbacks include likelihood of generating hum, increasing the possibility of electrical shock, and the excessive cost of relays with 120-volt AC coils, A well-engineered system will probably not be the one in which line voltage is used for control.

The chief disadvantage of low-voltage AC for control are cost of relays and the potential of hum problems. Low voltage DC seems clearly the best choice, and offers the fallout advantage of compatibility with transistors.

But what voltage? Relays are reasonably inexpensive for both 6- and 12-volt DC applications. These lower DC voltages, however, require larger current-carrying conductors than a 28-volt control system. A 6-volt system can readily be adapted to integrated circuit elements, but this compatibility is offset by the fact that steppers with 6-volt coils are so rare as to be virtually nonexistent.

Now consider some of the arguments in favor of a 28-volt system: Conductors can be small because 28-volt current drain will be below that of all lower voltages. The military's widespread use of 28-volt DC systems has helped to create an abundance of low-cost steppers and relays on the surplus market. And since 28 volts is such a 'nonstandard" standard, military surplus components operating from this supply voltage will nearly always sell for less than their 6- and 12-volt equivalents.

The 28-volt DC power supply will be less expensive to build, too. Practically any silicon rectifier will handle 28 volts; and the low current requirements of a 28-volt system contribute to its overall economy. The only remaining question is that of polarity. In most cases, it will be a 50/50 proposition. There is, however, one advantage to a negative-voltage 28-volt system. Its additional usefulness as a bias source for the transmitters, if necessary, can be a blessing if provisions for this have not been previously incorporated. If conventional base stations are used, this advantage loses much of its meaning because commercial base station power supplied have integral bias sources.

The power-supply circuit shown in Fig. 27-5 is a negative output type. By grounding the opposite end of the bridge (and ungrounding the other)

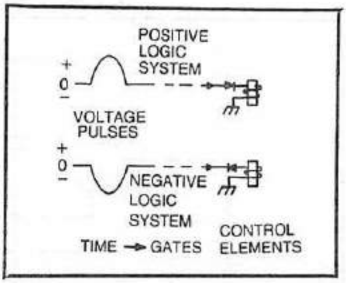


Fig. 27-6. Diode connections for control by means of polarity change.

and reversing the filter capacitor, the polarity is, of course, reversed. Care must be exercised when using diodes with negatively polarized systems; pulse 'travel" will always be cathode-to-anode, as depicted in the sketch of Fig. 27-6.

CTS CONTROL

While generally not a practical technique, there are circumstances where CTS control will work. Briefly, the technique is to encode a certain CTS tone for a few seconds (called the primary tone), then a second tone for two seconds (called the secondary tone). The second tone would correspond to a function. A possible circuit for the technique is shown in Fig. 27-7. This system is not practical unless you have only a few functions that you desire to remotely control, because you would need a method of encoding a number of tones. This could quickly get very unwieldy.

SINGLE-TONE AND DUAL-TONE SYSTEMS

These two control systems are not really practical for prime control of an Amateur repeater, but they are versatile enough to consider. We will

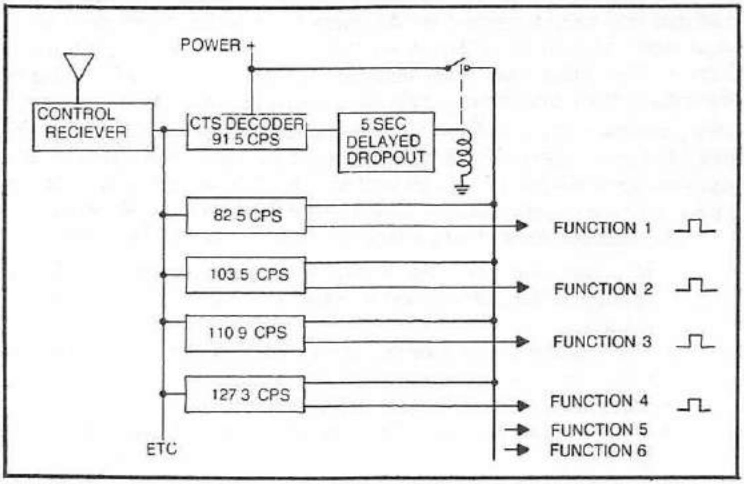


Fig. 27-7. Multiple control functions activated by tone decoders.

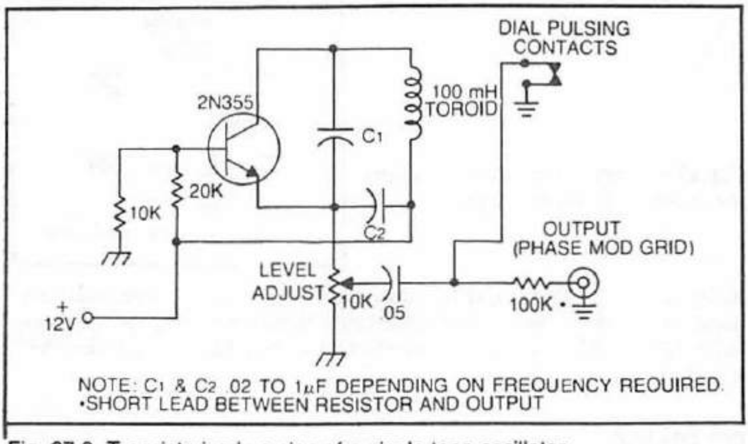


Fig. 27-8. Transistorized version of a single-tone oscillator.

first explain how they are used in commercial systems, and then explore their applications in the Amateur world.

Single-Tone

This technique has been used for years in the commercial field, for repeater-access control, paging systems, and many other applications. Single Tone is a very versatile system, but in its most basic form, the amateur world calls it "tone-burst." The California Highway Patrol has used this system for repeater selection for many years. One standard option in any commercial base station is the "alert" tone, which matches the single-tone decoder in the monitor receiver. These units are frequently used by volunteer fire departments, search-and-rescue services, etc. One advantage that commercial single-tone decoders have is that there must be a *single* tone , all by itself, with no voice modulating the carrier, or it will not decode. The author once tried building a Touch-Tone decoder using 8 Motorola P-9301 tube-type, single-tone decoders, but ended up putting series-resonant filters in front of each decoder before they would work. Individual group filters in front of each group of 4 wouldn't work because any voice energy in the band would prevent decode. This system worked better than a 567-type decoder, but not as well as the WA6AWD unit shown later.

The amateur uses of single-tone are based upon the facts that:

- In single-tone's heyday, Touch-Tone hadn't been around long enough for encoders (pads) or decoders to show up in the Amateur market.
- The available single-tone decoders were accurate — ± 200 Hz, or narrower, was not unusual.
- They were fast—40 mS or better was the norm.
- They were inexpensive. Generally, $5.00 would buy a decoder or an encoder.
- The decoders interfaced to a stepper or a Strowger relay easily, and a telephone dial could be connected to a encoder just as quickly.

The encoder circuit shown in Fig. 27-8 was designed by Bob Mueller, (K6ASK), as a standard, but stabilized, simple pulsed audio oscillator. The circuit features a very high Q for stability, a single transistor for simplicity, and tiny components for the utmost in miniaturization. The circuit can be constructed on a circuit board, or the more readily available perforated phenolic sheet.

The most critical element of the encoder circuit is the distance from the 100k series resistor in the output to the input of the mike amplifier (or phase modulator grid) of the transmitter. The most satisfactory installation will be achieved if the resistor can be mounted close to this point. Leads should be kept as short as possible, of course.

The actual frequency of operation is governed by selection of C_1 and C_2. Their values will be somewhere between 0.02 and 1.0 μF, determined on the basis of experimentation.

The July 1968 issue of FM Magazine carried a construction article by Gary Hendrickson, W3DTN which gave detailed circuit data for two ubiquitous single-tone encoders that are designed to work with 'interruption" pulsing (rather than straight tone pulsing). One was a hand held job that could be used to generate an audio signal for transmission through a conventional microphone; the other—a little more complex—was designed for permanent mounting in a mobile installation .

The hand-held version can be built small enough to be used anywhere—at the fixed station, in a mobile, or with a walkie-talkie; yet it retains the desirable characteristics of simplicity and high reliability.

The speaker on Hendrickson's portable sender is the receiver element from a conventional "500" series telephone handset. He reportedly tested several types and found that the "500" most easily drives a microphone to full modulation without added amplifier circuitry.

Figure 27-9 shows the schematic for the portable sender. The single transistor is of a noncritical type, and any PNP with an h_{FE} of 50 to 100 can be readily substituted. An NPN transistor can be used if all supply voltages,

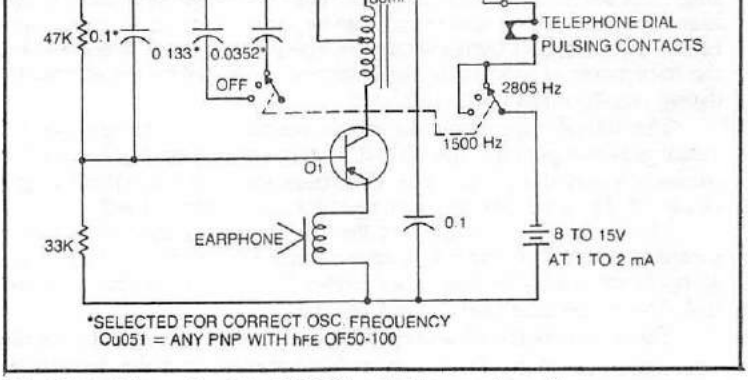


Fig. 27-9. Schematic of the W3DTN portable encoder unit.

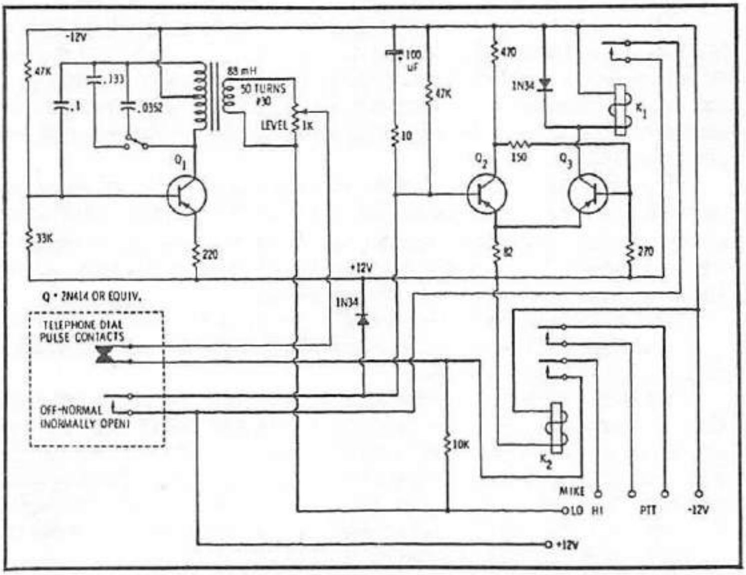


Fig. 27-10. Schematic diagram of a mobile secode-type decoder.

diodes, and other polarized circuit elements are reversed. The 88-mH toroid is the standard telephone "loading" coil familiar in RTTY circles. It consists of two windings; the adjacent ends at the center are tied together to obtain the centertap.

The frequency-determining capacitors should be good-quality Mylar types for best temperature stability. Small values can be paralleled here to produce the precise oscillating frequency desired. The two tone frequencies shown (1500 and 2805 Hz) are standard with commercial single-tone pulsing systems.

Figure 27-10 shows the more complicated single-tone encoder for use in permanent mobile installations. In this version relays K_1 and K_2 can be a single unit since they operate together. The two-transistor Schmitt trigger is an automatic-shutoff timer which can be set for just that amount of time required to perform a dialing sequence. The purpose of the timer is to key the transmitter as soon as the dial is moved and hold it on the air until the dialing sequence has been completed.

The 100-μF capacitor in the mobile sender can be changed to effect variation of the period if the shutoff time is unsuitable. As the circuit is shown, the period is 2.0 seconds. (The transistors for the Schmitt trigger can be of the same type as those used for the oscillator itself.)

The function of a single-tone decoder is nothing more than that of providing a contact closure with each incoming signal, the Strowgers and steppers are readily wedded to a decoder for effective multifunction control. This is discussed later in this chapter.

The most important features of a good decoder are frequency stability and signal selectivity. Frequency stability assures that the decoder will respond to proper signals during virtually any climatic conditions; selectivity affords a degree of security in that a selective decoder will not respond to signals out of a narrow bandpass.

The transistor circuit shown in Fig. 27-11 makes an ideal candidate for control because it does have the desirable characteristics of stability, selectivity, and it has the additional quality of being inexpensive to build. K6ASK designed this unit as a simplified version of Motorola's commercial single-tone decoder unit. The schematic shown is the third generation in a family of progressively improved decoders of K6ASK's design. The unit has a variable gain control on the input for establishing the proper sensitivity of the decoder, and a dc amplifier on the output for providing solid drive to the pulser relay.

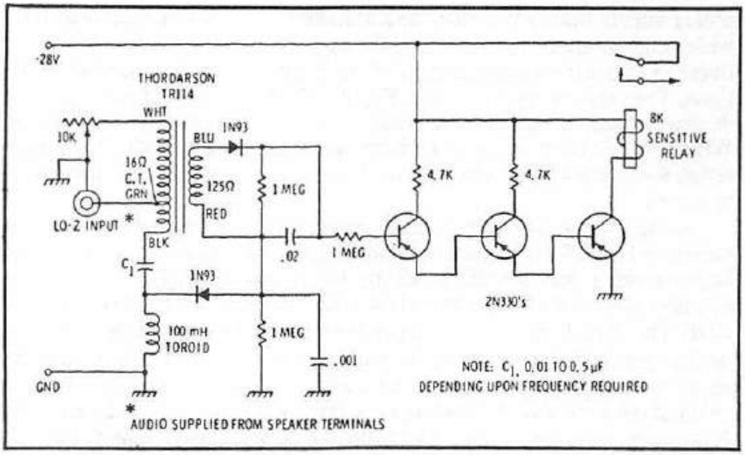
The decoder is designed for use with a 28-volt dc power source. When properly driven, the unit will respond to pulses within a bandwidth of less than 100 Hz (depending on sensitivity setting), and will reject all other tone signals.

The decoder is designed to accept tone signals directly from the speaker terminals of the remotely situated receiver (or from the audio amplifier if no speaker is used). Signals of the proper frequency and level are passed through the frequency-sensitive circuitry to the dc amplifier to key the current-operated "sensitive" relay at the output. This relay provides the pulses for controlling the mechanical stepper, Strowger switch, or other device. Note: The current-operated relay is not used to drive the stepper directly because of the delicate structure of its contacts; instead it is used to pulse a husky relay which in turn does the actual pulsing of the stepper.

Figure 27-12 shows the versatility of a single-tone system, which can use either a pulsed or interrupted tone.

Integrated-Circuit Control

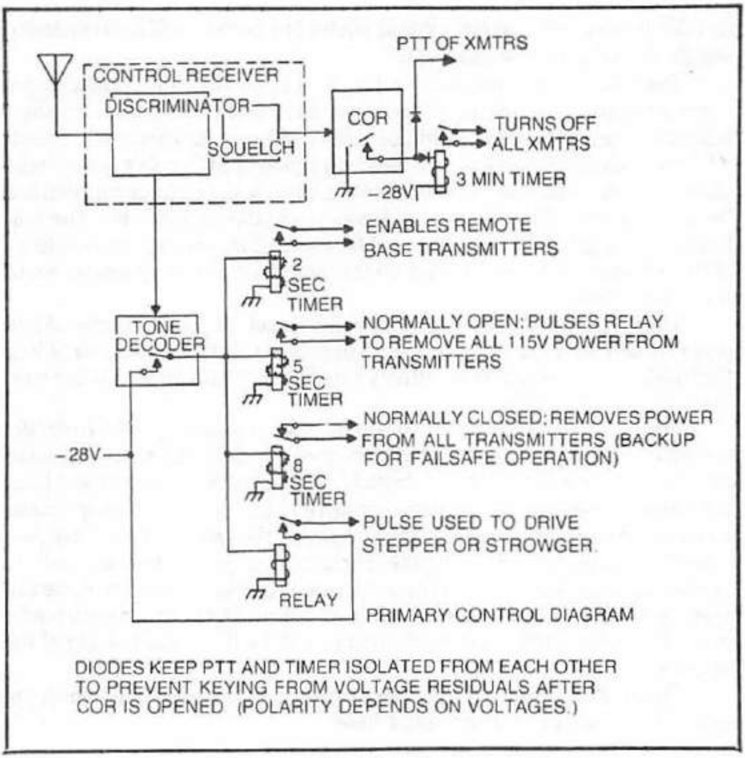
Most remote sites are characterized by wide variation in temperature and humidity. Line voltages may vary anywhere from 95 to 125 volts.



NOTE: C_1, 0.01 TO 0.5 µF DEPENDING UPON FREQUENCY REQUIRED

* AUDIO SUPPLIED FROM SPEAKER TERMINALS

Fig. 27-11. Single-tone decoder unit.


PTT OF XMTRS
CONTROL RECEIVER
DISCRIMINATOR
SQUELCH
COR
TURNS OFF ALL XMTRS
3 MIN TIMER
-28V
ENABLES REMOTE BASE TRANSMITTERS
2 SEC TIMER
TONE DECODER
NORMALLY OPEN; PULSES RELAY TO REMOVE ALL 115V POWER FROM TRANSMITTERS
5 SEC TIMER
NORMALLY CLOSED; REMOVES POWER FROM ALL TRANSMITTERS (BACKUP FOR FAILSAFE OPERATION)
-28V
8 SEC TIMER
PULSE USED TO DRIVE STEPPER OR STROWGER
RELAY
PRIMARY CONTROL DIAGRAM

DIODES KEEP PTT AND TIMER ISOLATED FROM EACH OTHER TO PREVENT KEYING FROM VOLTAGE RESIDUALS AFTER COR IS OPENED (POLARITY DEPENDS ON VOLTAGES.)

Fig. 27-12. An example of versatility using single-tone system.

Considering the vertical voltage requirements of integrated circuits, and the expense of replacement, it seems almost foolhardy to construct a power supply that cannot provide a stabilized, nonvarying output under a wide range of inputs. A second consideration is protection for the IC's in the event of inadvertent short circuits of other unforeseen high-current conditions. The power supply shown in Fig. 27-13 offers a sound first step in the design or construction of an IC control system. Designed by Tom Woore, WB6BFM to power an integrated-circuit identifier for the W6FNO repeater at Radio Ranch, the circuit provides sturdy regulation and short-proof operation.

A simple, well-proved control system utilizing integrated circuits is shown in Fig. 27-14. The circuit shown is the result of a series of design improvements and simplifications by Gil Boelke (W2EUP), one of the sharpest solid-state design men in the country. A parts list is given in Table 27-1. The Buffalo repeater in upper New York State has been controlled with a system of this design for the past year without failure. As a consequence, more and more repeaters are switching to similar designs. While it may not offer some of the control versatility of the mechanical devices, the IC system has all the combined attributes of compactness, ruggedness (and attendant reliability), absense of moving parts, and simplicity.

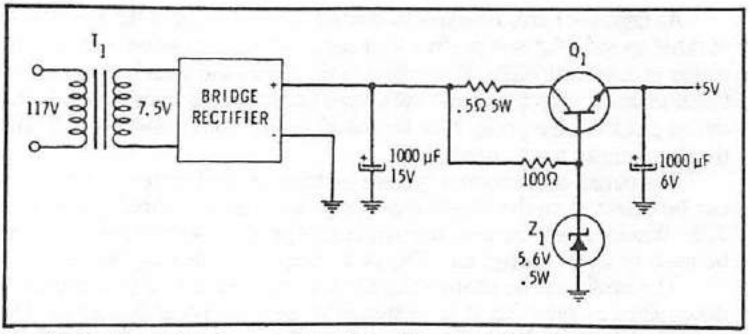


Fig. 27-13. A regulated power supply for integrated circuits.

The integrated circuit control system was designed to be used with an interrupted single-tone input, though it is readily adaptable to a straight digital single-tone pulsing scheme. The complete circuit can be built on two average-size circuit boards, yet it contains all the necessary control elements, including tone decoder (referred to as a tone detector on the schematic), timers, digit and pulse counters, and coding networks.

Table 27-1. Parts list for W2EUP decoder.

Q_1	Motorola HEP 245
Z_1	1N5230, 5.6V, 0.5W
BR	Full-wave bridge, Motorola HEP 175
T_1	117 VAC Pri—7.5 VAC Sec. 1A
Q_1, Q_3, Q_5	2N5133 Fairchild NPN transistors
Q_2	2N5307 GE Darlington Pair
Q_4	General purpose unijunction transistor
C_1	5-µF, 6V, electrolytic capacitor
C_2	5-µF, 3V, electrolytic capacitor
C_3	.033-µF, mylar capacitor
C_4	1-µF, 6V, electrolytic capacitor
C_5	0.22-µF, paper capacitor
C_6	100-µF, 6V, electrolytic capacitor
C_7	1.3-µF, 6V, electrolytic capacitor
C_8	39-µF, 6V, electrolytic capacitor
C_9	10-µF, 6V, electrolytic capacitor
D_1-D_{16}	1N914 or 1N625 Silicon diodes
R_1, R_7	10K, ¼-watt (or greater) resistor ±10%
R_2, R_9	5.1K, ¼-watt (or greater) resistor ±10%
R_3, R_5, R_6, R_{11}	1K, ¼-watt(or greater) resistor ±10%
R_4	220K, ¼-watt (or greater) resistor ±10%
R_8	56K, ¼-watt (or greater) resistor ±10%
R_{10}	100Ω, ¼-watt (or greater) resistor ±10%
R_{12}	3.3K, ¼-watt (or greater) resistor ±10%

As depicted here, Boelke's IC control system requires the processing of three specific digits (a prefix code) before an output can be obtained (by dialing of the fourth digit). Regardless of the inputs and input sequences, no function can be selected unless the proper prefix code is transmitted. In the circuit pictured, the prefix code for function selection consists of 7, 2, and 6—sequentially transmitted.

The output of the control system contains ten AND gates, any of which can be selected on the fourth digit (provided the prior three digits were 726). When pulsed, the selected output gate provides a short pulse that can be used to latch a relay, an SCR, or a transistor switching device.

The prefix can be changed by the control operator. The sequence is determined by selection of drive signals at the digit recognition gates. The pulse counter (which supplies these drive signals) contains five flip-flops; since each flip-flop has two states (set and reset, on and off, 1 and 0, etc.), there are ten possible single conditions. In operation, the first pulse changes the state of the first flip-flop from A to A , but the second flip-flop (B) remains unchanged. The code, then, for the digit 1 would be AB. The next pulse triggers B to the B state, leaving C unchanged; so the digit 2 would be represented by BC. Thus, to change the prefix code from 726, the digit recognition gates (numbered 10, 11, and 12 on the schematic) would have to be reprogramed according to these logic equations:

1 $\bar{A}B$ 6 $A\bar{B}$
2 $\bar{B}C$ 7 $B\bar{C}$
3 $\bar{C}D$ 8 $C\bar{D}$
4 $\bar{D}E$ 9 $D\bar{E}$
5 $\bar{E}\bar{A}$ 0 EA

Close examination of the table will reveal what may appear to be an inconsistency in the programing scheme. In all cases but digits 5 and 0, the following stage is of an opposite state. The schematic shows an inversion of the output of the fifth flip-flop, however. This inversion is necessary to reset the flip-flops after the first five have been set, and to set the first after the last has been reset. Unlike other counters, which contain a series of flip-flops each of which will trigger the preceding stage, this one contains flip-flops that stay in their pulsed state until actively changed by the incoming digital train. At the conclusion of each digital train, all flip-flops are reset to allow counting of the next incoming pulse series.

Mechanical Control

By far the most common and inexpensive method for multifunction control is the use of a conventional "telephone-type" stepper as the system brain. Figure 27-15 is a diagram showing an extremely simple means for the remotely controllable selection of up to 10 functions. In the plan illustrated, a negative supply voltage (−28 volts) is used for control and pulsing. The decoder, which provides a −28 volt pulse with each tone pulse transmitted, is not shown. As shown, the pulse voltage is supplied through a diode which isolates the stepper potential from the decoder. (The diode must be reversed, of course, if a positive control voltage is used.)

Many steppers have a "step cam" contact that provides a closure as soon as the stepper is moved off normal. This contact supplies control voltage to the normally closed COR contacts. When the stepper does not

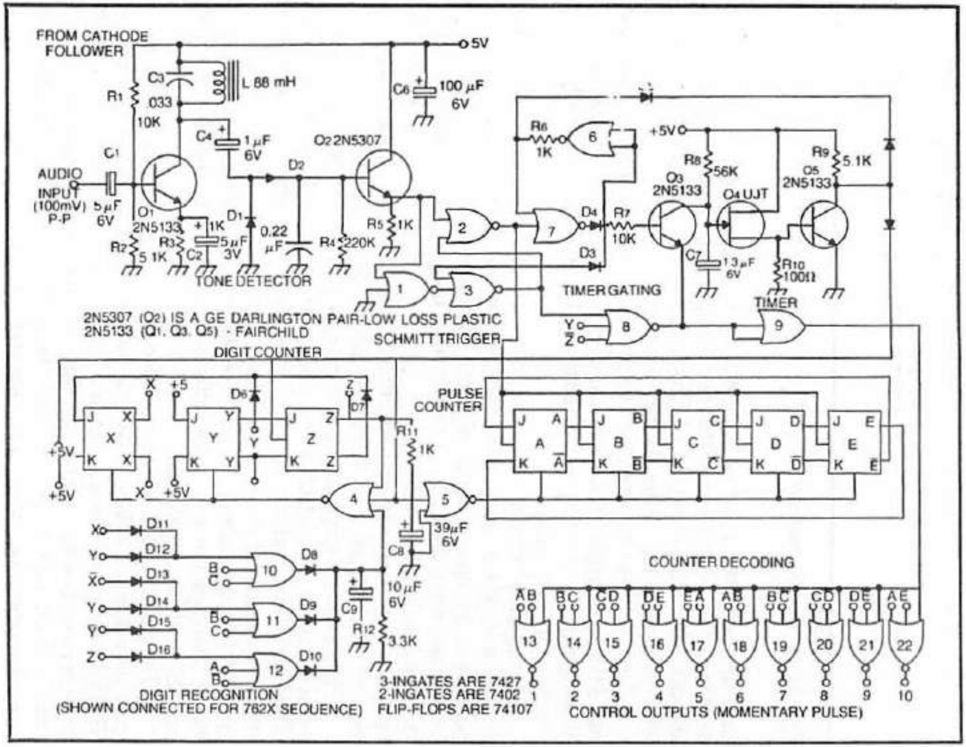


Fig. 27-14. The W2EUP single-tone decoder and control logic.

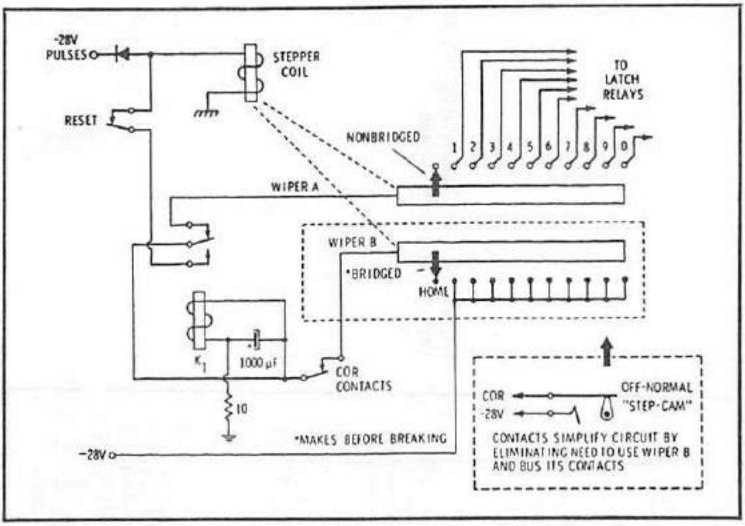


Fig. 27-15. Simple repeater "brain."

have this capability, it can be simulated by bussing all the contacts of one deck together and connecting that deck's wiper arm to the COR contact as shown in the sketch of Fig. 27-16. This keeps control voltage off the wipers when the stepper is at the "home" position.

Steppers also characteristically have reset contacts, which are nothing more than a normally closed set that opens momentarily with each pulse. When a continuous voltage is applied here, the switch pulses rapidly until it reaches the home position.

In the circuit illustrated control pulses from the decoder are fed to the stepper coil, which causes the wiper arms to step to the position corresponding to the digit transmitted at the control point. While the digits are being transmitted the COR is pulled in, thus keeping relay voltage from the reset circuit (K_1). When the digital sequence has been dialed and the control operator stops transmitting momentarily, the COR closes, supplying voltage to the 1000-μF capacitor on K_1 and feeding wiper A.

The 10-ohm relay and large electrolytic on K_1 act to delay the relay's response while the control voltage pulses the contact selected by wiper A. Then, after the capacitor charges, it pulls in K_1 to remove voltage from wiper A and trigger the stepper's reset function. The bussed contacts of wiper B keep voltage on K_1 until the wiper moves off contact 1 toward home. The capacitor at K_1 holds sufficient charge to keep the reset in action and the cycle is completed.

The result of the above operation was the appearance of a voltage pulse of a hundred milliseconds or so on the selected contact of wiper A. Had a latching relay been connected at that point, a useful function would have been successfully switched. Figure 27-16 shows a stepper brain which uses a timer rather than a timed relay. This offers the advantage of precision operation under all voltage and temperature conditions.

Stepper Considerations

Stepper switches are usually equipped with two or more wipers for simultaneously switching all legs of the circuits being controlled. Wipers are most frequently of the nonbridging type, which leave one contact completely before coming into contact with the next (make after break). In some cases, however, it is desirable that the circuit through the switch wipers be maintained without interruption throughout the complete selection or reset process. To accomplish this, most steppers have at least one bank of bridged contacts; that is, the wiper makes contact with each step before breaking the contact of the previous step. In all cases, wipers touch only one contact when at rest.

The length of time the circuit is closed (or open) in a series of fast pulses is important. To be fully effective, a pulse to the stepper must consist of an "on" interval (coil current flowing) long enough to attract the switch's armature into a cocked position, storing potential energy in the drive spring while doing so. The "off" time interval must be adequate for the drive spring to move the armature and wiper assembly to the next bank contact position. For a series of nearly constant-speed pulses this can be expressed as "percent make" (closed-coil circuit) and "percent break" (open-coil circuit) as related to the overall span of a single pulse. At 10 pulses per second (the generally adopted standard because of compatibility with telephone dialing speed), a percent make of 80 percent and a percent break of 20 percent would represent a pulse "on" time of approximately 80 milliseconds and an "off" time of about 20 milliseconds. This is an ideal condition for most stepping devices.

The pulse-and-reset stepper shown in Fig. 27-17 is the most universally used, but the Strowger (a two-axis equivalent) is gaining in popularity. The Strowger is a bit more complex than a conventional stepper, but it is extremely reliable and offers the advantage of built-in resettability, two-digit operation, and a multiple-function capability. The Strowger is still in

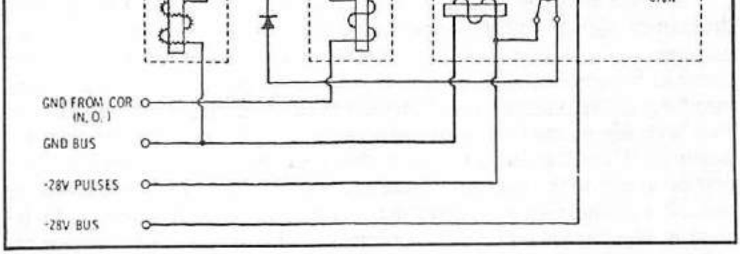


Fig. 27-16. Universal stepper circuit using timer for precision pulse-period control.

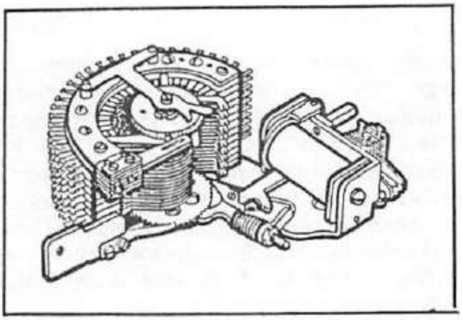


Fig. 27-17. Standard rotary stepper switch.

common use by telephone companies as line finders, selectors, and "seekers." Without special modification, a conventional stepper will restrict the user to ten functions (the number of digits on a telephone dial); the Strowger two-digit system allows the selection of 100 discrete switch positions. Figure 27-18 shows the Strowger switch.

Strowger Considerations

The Strowger two-motion stepper switch will select any desired circuit from among a possible 100 circuits in approximately two seconds. The wipers move first upward, then rotate horizontally, over two contact banks of 10 levels, with 10 contacts per level. The contact arrangement is illustrated in Fig. 27-19.

The stepping mechanism includes the wipers, the shaft on which they are mounted, and the mechanical devices which raise and rotate the shaft. Figures 27-18 and 27-19 show two views of a typical Strowger and identifies the parts. As illustrated, the contact wiper assembly is carried by the vertical and rotary motion of the shaft. The wipers are positioned on the switch shaft so that they are raised and rotated (all together) to the same relative position on each bank.

The switch is raised, rotated, and released to its normal position (up, around, and return motions) by combinations of electromagnets, armatures, pawls, ratchets, and detent mechanisms. The interacting parts are designated vertical, rotary, or release, according to the motion each imparts to the movable shaft.

The switch is operated by a series of pulses controlled by the dialed number (six pulses for the number 6, two for the digit 2, etc.).

As nice as single-tone is, there is one major problem: A momentary dropout of signal, flutter during dialing for example, results in a wrong number, and unless the control operator is using full duplex, he'll never know it. Several techniques were developed to get around that problem, resulting in "interrupted tone" instead of tone pulsing. With interrupted-tone techniques, the tone is turned on when the dial is taken off of it's home position. When the dial is released, the contacts open a number of times proportionate to the number dialed, causing interruption of the continuous tone. If a second digit is required in the control scheme, the tone continues (and is interrupted again in accordance to the second digit). When the pulsing process is complete, the tone is removed either manually or by a timer. Removal of the tone triggers the function.

Generally, voice tripping is avoided by requiring a continuous decode for a half second before any interruptions, wrong numbers can be partially avoided by requiring 1 second of tone after the last interruption. Then, if a flutter "punches a hole" in the tone, the decoder would see one of two things: 1. Early end-of-dialing—the tone dropped off after the first of two digits; abort the function and squawk a tone when the COR releases. 2. Early and-of-digit—the tone dropped off during a digit possibly due to flutter; the 1-second-of-tone after a second digit, or between digits wasn't there, therefore abort the function.

Both of these techniques had problems, because one state of the data—either the "on" or the "off" of the decoder relay—was identical to the "no-tone" condition on the decoder input and a noisy or fluttery signal resembled that same state. Enter Dual-Tone.

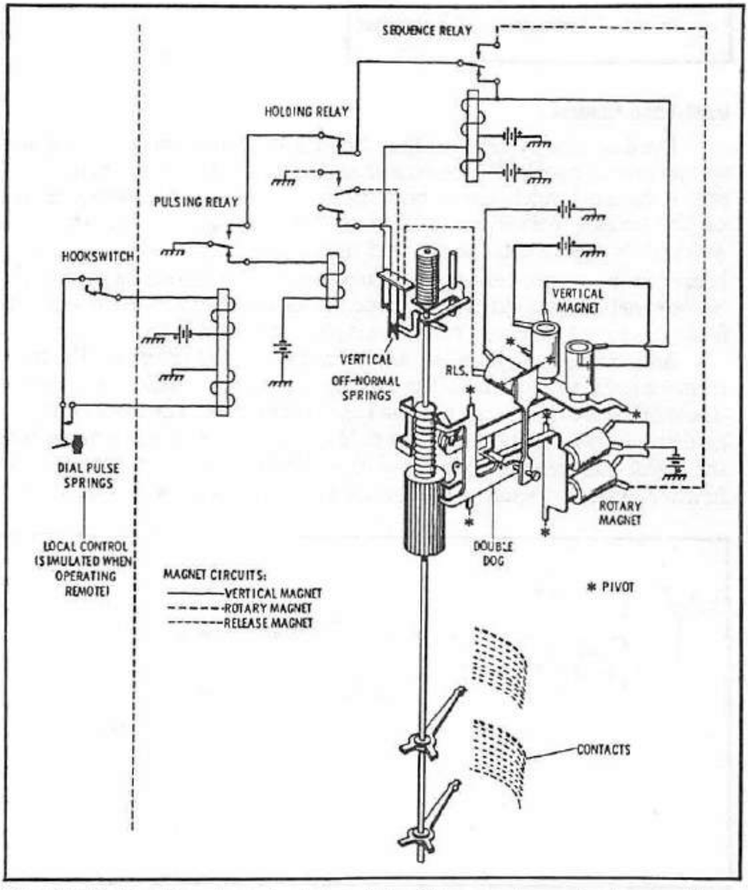


Fig. 27-18. Functional mechanisms of the Strowger two-axis stepper. Even though the diagram shows seven batteries, one supply can be used if it will handle the peak current loads.

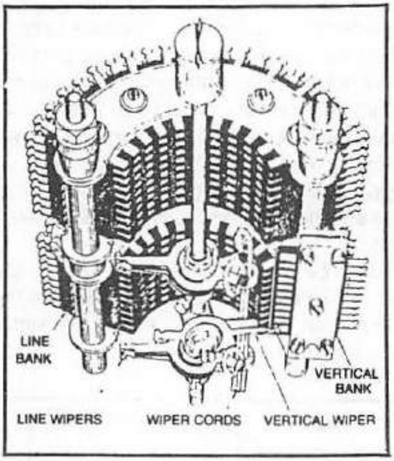


Fig. 27-19. Contact arrangement of the Strowger two-motion stepper switch.

Dual-Tone Control

The dual-tone system was first widely used in the radio field to signal a certain mobile telephone unit on a shared channel. The trade name "Secode" is the most widely known brand name. The Secode decoders available on the surplus market are mechanical marvels using ratchet wheels to accept 5 to 8 sequential digits, and then close a relay (which triggers a buzzer in the mobile-telephone control head). The unique method in the Secode units is that either tone alone means nothing, it is the transitions from one tone to the other that steps the ratchet wheel.

Amateur uses of the dual-tone technique are a bit different. The most common use is to avoid most of the wrong numbers in a single-tone system. The method is to have tone present in both states of the decoder output. If neither tone was present during a dialing sequence, it would indicate that the signal was weak, or otherwise unusable. This would discontinue the function. A block diagram of the decoding technique is shown in Fig. 27-20.

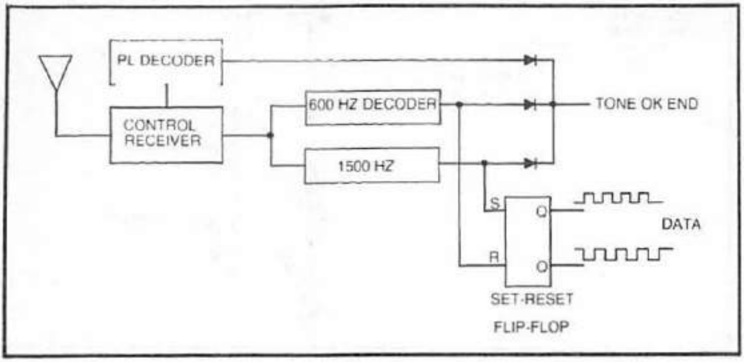
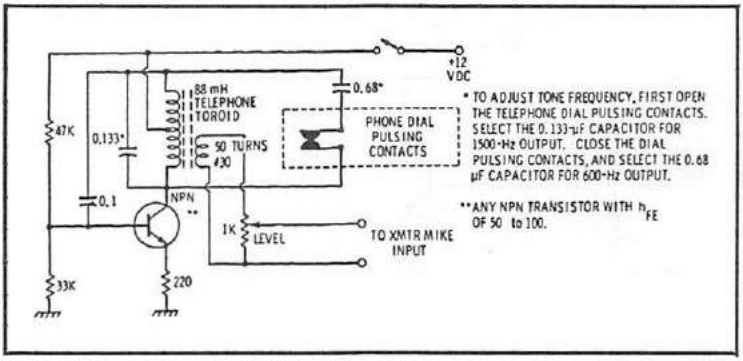


Fig. 27-20. Using a PL decoder and two high-frequency tone decoders to obtain multiple control functions.



* TO ADJUST TONE FREQUENCY, FIRST OPEN THE TELEPHONE DIAL PULSING CONTACTS. SELECT THE 0.133-μF CAPACITOR FOR 1500-Hz OUTPUT. CLOSE THE DIAL PULSING CONTACTS, AND SELECT THE 0.68 μF CAPACITOR FOR 600-Hz OUTPUT.

** ANY NPN TRANSISTOR WITH h_{FE} OF 50 to 100.

Fig. 27-21. Dual-tone (600/1500 Hz) oscillator.

The tone frequencies for dual-tone systems are typically 600 and 1500 Hz. Figure 27-21 shows a schematic for an encoder capable of providing a sequential transmission of these two tones. The circuit was designed by Gary Hendrickson W3DTN. The frequency-variation technique is described on the schematic.

An example of how a pair of single-tone decoders can be used to decode dual-tone commands is shown in Fig. 27-22. It is designed to interface with either the stepper of Fig. 27-17 or the Strowger of Fig. 27-18.

TELEPHONE CONTROL

A not-too-often considered means of remote control is the telephone itself (assuming a telephone is available at the remote site). As a principal

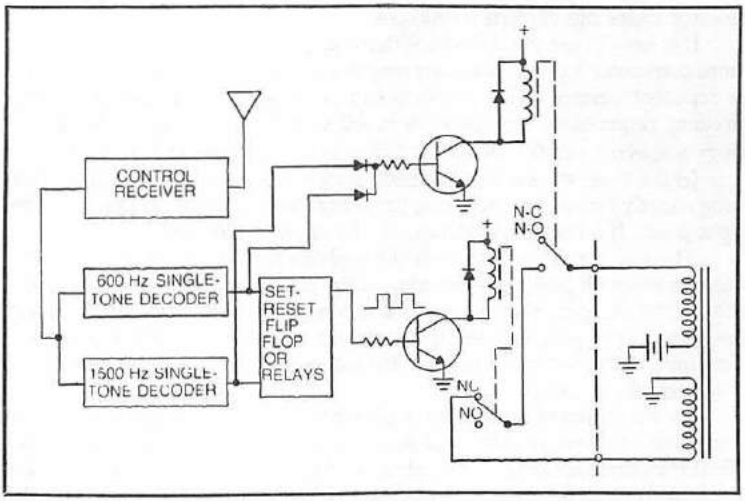

CONTROL RECEIVER
600 Hz SINGLE-TONE DECODER
1500 Hz SINGLE-TONE DECODER
SET-RESET FLIP FLOP OR RELAYS
+
+
N-C
N-O
NC
NO

Fig. 27-22. Decoder and control with the two-tone system.

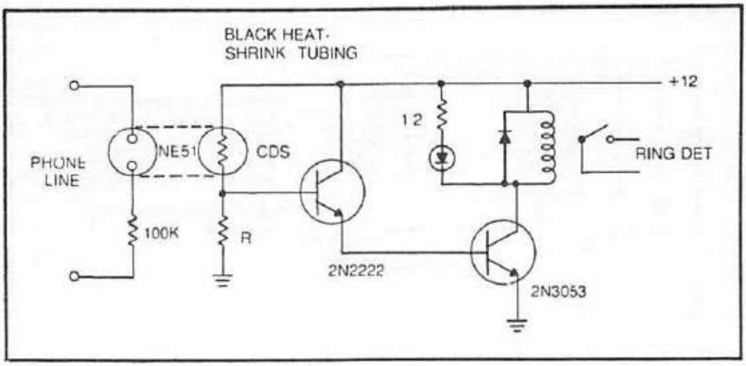


Fig. 27-23. A ring-detector that is isolated from the telephone line through an optical coupler.

control element, the telephone has certain disadvantages, but as a backup system, the telephone has no equal. There is no feeling quite as comfortable to a remote or repeater owner as the knowledge that he can shut down his system regardless of what happens to the hilltop transmitter or receiver and regardless of where he is. For he knows that to accomplish shutdown, he need only go to the nearest telephone and dial the remote number. When the remotely situated telephone rings, the shutdown function will occur.

The circuit in Fig. 27-23 shows a ring detector that the author has used with success in a number of different applications. The CDS cell used in the author's units were unmarked surplus, and the resistor "R" was different for each type of cell, although they varied from 100K to 1M. The author sanded an area on the NE51 shell and soldered to it, and then encased the lamp and cell in black heat-shrink tubing, with the lamp touching the cell.

The neon bulb is an open circuit until it fires, and then the 100K resistor limits the current to 900 μA

It is easy to see the difficulties that could arise if the telephone number were commonly known, since any ring would cause immediate interruption of repeater service. This problem can be avoided by adding the extra circuitry required so that the system will shut down only when the phone rings a specific number of times. This circuit is shown in Fig. 27-24.

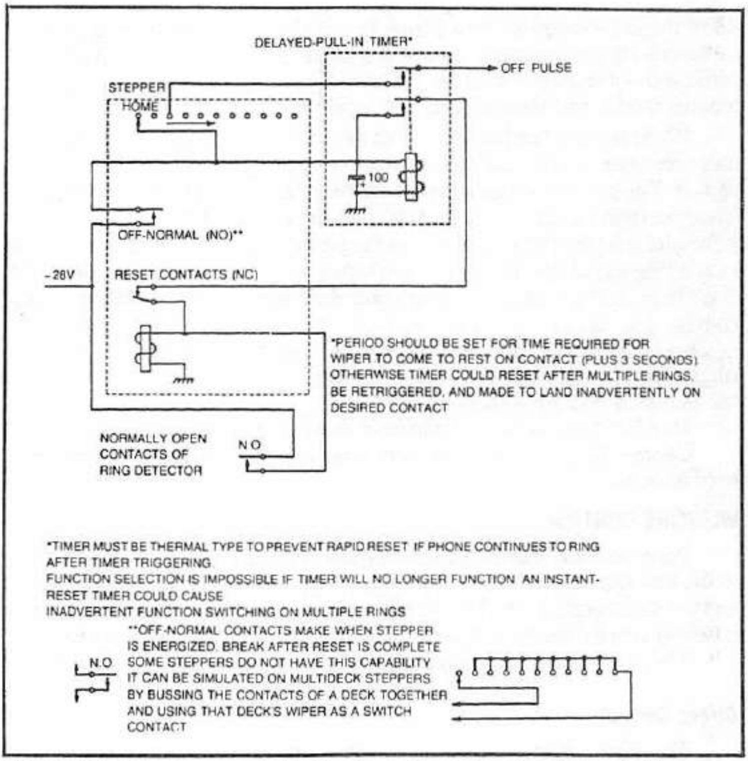
In the case shown, the desired function occurs when the phone has rung exactly twice. The first ring prevents the stepper from reaching the right point. If a third ring occurs, the function is canceled.

The function occurs only when the phone has rung two times and the stepper rests on position 2. Ringing of the phone energizes the timer and moves the stepper; the stepper will automatically reset after it has been energized. The period of the timer should be selected to allow sufficient time for the stepper wiper to come to rest on the coded "off" contact with a few seconds to spare.

Incorporation of an automatic phone patch into a remote system will introduce some interesting (and somewhat amusing) control possibilities. Most telephone areas have individual numbers which can be dialed to make the initiating telephone ring. Using this capability, a remote operator can initiate a call to this "ringback" number, hang up, then let his on-site telephone ring the specific number of times required to perform the intended "off" function.

For obvious reasons, telephone control should be reserved exclusively for "off" commands. The FCC would frown (to say the least) on a remote system that opened the possibility for a "wrong number" to turn on repeater equipment. The concept of telephone control can be extended to cover the contingencies of wrong numbers very easily. The two techniques that the author has heard of are:

1. The phone rings "N" number of times, then stops, then rings "M" number of times to accomplish the desired function. The group involved used only two functions, and used two different "second numbers" to select them: One was RPT off, the other was "Connect phone line to command system audio in."
2. Answer the phone on the first pulse of the first ring (the calling party will never hear it ring), and use a phone patch to couple a "number not in service" recording into the line. Simultaneously monitor the line with a Touch-Tone sequence decoder plugged into the microphone jack on the phone patch. If you get the right number sequence, turn off the recording and enable the command system to the line. A diagram of this hookup is shown in Fig. 27-25.



*PERIOD SHOULD BE SET FOR TIME REQUIRED FOR WIPER TO COME TO REST ON CONTACT (PLUS 3 SECONDS) OTHERWISE TIMER COULD RESET AFTER MULTIPLE RINGS, BE RETRIGGERED, AND MADE TO LAND INADVERTENTLY ON DESIRED CONTACT

*TIMER MUST BE THERMAL TYPE TO PREVENT RAPID RESET IF PHONE CONTINUES TO RING AFTER TIMER TRIGGERING
FUNCTION SELECTION IS IMPOSSIBLE IF TIMER WILL NO LONGER FUNCTION AN INSTANT-RESET TIMER COULD CAUSE
INADVERTENT FUNCTION SWITCHING ON MULTIPLE RINGS

**OFF-NORMAL CONTACTS MAKE WHEN STEPPER IS ENERGIZED. BREAK AFTER RESET IS COMPLETE SOME STEPPERS DO NOT HAVE THIS CAPABILITY IT CAN BE SIMULATED ON MULTIDECK STEPPERS BY BUSSING THE CONTACTS OF A DECK TOGETHER AND USING THAT DECK'S WIPER AS A SWITCH CONTACT

Fig. 27-24. Telephone control with planned code for function switching.

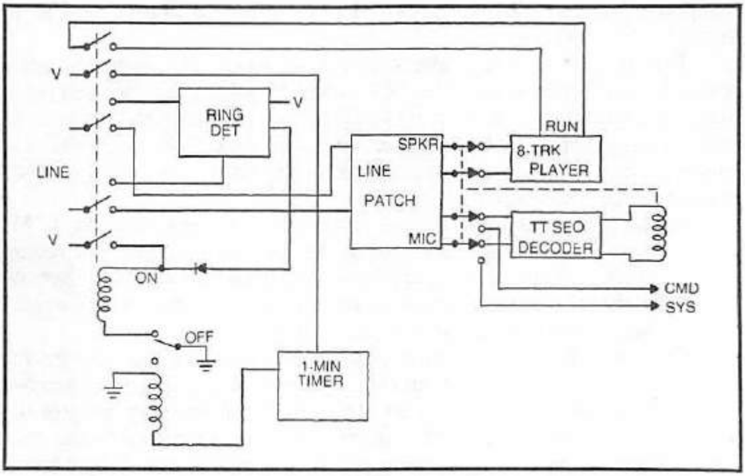


Fig. 27-25. Multiple command/control functions using a telephone line to the repeater site.

All of these techniques use a phone line at the site. If you intend to have autopatch on your system, do use the same phone line for autopatch and command—you might want to command your system when it is in autopatch mode, and then all that you would get is a busy signal.

When using a telephone control system, there is one point that you must consider. The signal that is used to ring the phone is roughly 50 % on and off. The generator that runs the exchange has two "phases" or outputs. Under certain conditions, the "ring" that the calling party hears is not the same phase as the "ring" that drives the phone. In simple words, when you hear a ring signal, the phone can be ringing when you hear it, or when you don't hear it. If you find that your control system is always getting wrong counts, you can take the easy way out. One group uses three different numbers, and simply puts a "blip" on the repeater audio when the phone rings. They count blips, and ignore the extra ones that the system puts on the end as a confusion factor.

One last thing about telephone-control systems:

Change the phone number every three months, whether you think you need to or not.

WIRELINE CONTROL

Wireline control is of two basic types, AC and DC. AC wireline refers to the techniques used when there is no DC path between the control point and the radio equipment. DC wireline is used when there is a DC path and different current levels of different polarities can command the equipment.

There are two basic variations of the two types—direct and indirect.

Direct Control

The direct-control approach, more common with commercial users than amateurs, involves the direct transmittal of signals to a remote site via the wireline. Indirect control is the use of a wireline as a link, ordinarily employed to interconnect two remote facilities.

The direct-control system has never been particularly popular with amateurs because its use restricts control (and often operation), of the remotely located equipment, to the operator at a single fixed point. The trend to mobility—in both control and communication capability—has resulted in the modern amateur all but ignoring the use of wirelines for control.

The wireline's compatibility with an open repeater system and its built-in security from unauthorized control access should qualify it for serious consideration as a primary control mode in repeater systems which are still in the design stage.

There are a number of instances where wireline control becomes economically or technically more feasible than radio control.

Where the remote site is situated only a short distance from the control point, the technical and economic advantages of wire can often outweigh those of a system controlled solely by radio. The single pair of a leased wireline circuit is used to convey all the elements for control and communication; in most cases the wireline's dc transmittal capability obviates the need for tone encoders and decoders.

While many of the tone-control techniques previously described are readily adaptable to wire transmission, certain additional factors (for example, levels, impedances, etc.) must be considered when using leased telephone pairs. This section outlines the basic applications of wireline "links" and describes the principal methods for assuring reliable control capability and consistent, effective communications.

The wire that connects the primary site (the control point), to the secondary site (the equipment location), may be leased from the telephone company, or it may be Amateur-owned, and Amateur-installed. If you elect to do it yourself, find out what kind of cable the phone company would use, and use that type. After all, they have been in the business of running cables for a lot longer than you have, and you might as well benefit from their experience.

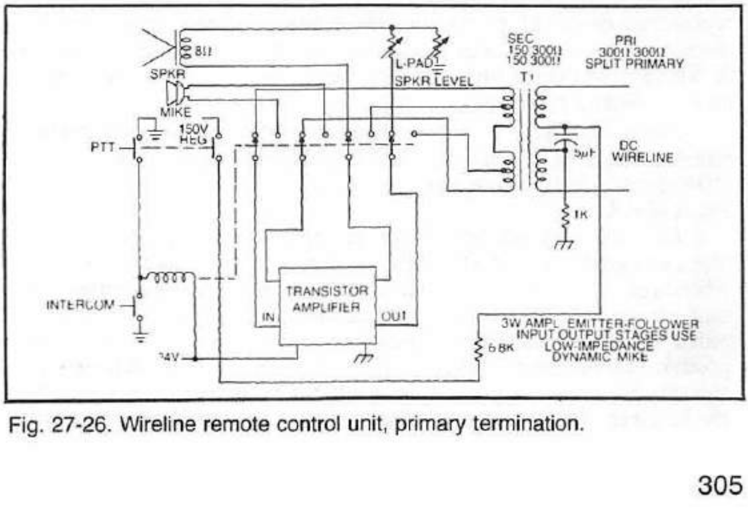


Fig. 27-26. Wireline remote control unit, primary termination.

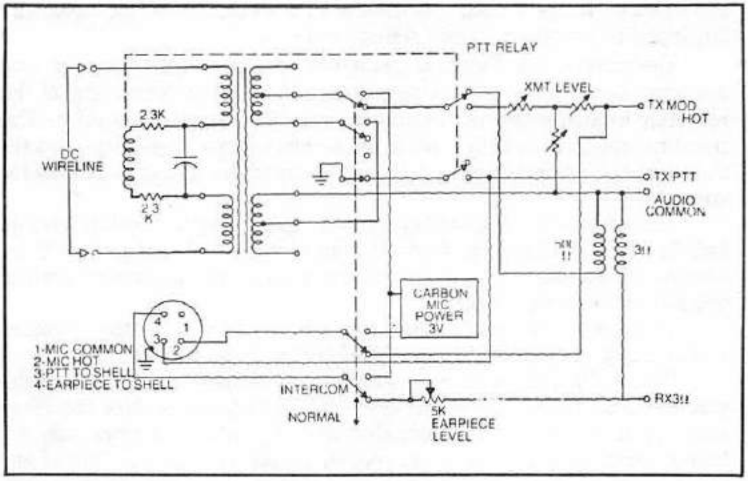


Fig. 27-27. Wireline remote control unit, repeater termination.

Figures 27-26 and 27-27 show a good example of a direct control DC wireline setup. Note that there is no reason why two or more primary units could not be put on the same line. In fact, the person who donated the schematics has 4 units, built into old telephone sets all over his house with the base station in the shop. The rotary dials were replaced by speakers, and a PTT switch installed in the handset, with the fourth handset wire conductor run to a relay for the PTT function.

Perhaps the most "natural" application of a wireline in a repeater system is between a transmitter and a receiver site when the two installations are separated by a short distance (usually less than a mile). This constitutes indirect control in that no operator monitors or provides direct control at either terminal point of a single wire pair.

Figure 27-28 illustrates this concept, and shows how it may be used in combination with a radio-controlled repeater system. By using control techniques described previously, the control operator may connect or disconnect the wireline or perform any other off-on function at repeater site A. There is no reason why a direct control unit could not be incorporated into the control system.

Site B (where the receiver is deployed) is coupled, via the wireline, to site A through the wireline circuitry. Signals from site B to site A, such as COR closures and audio, are processed through subcontrol circuitry installed at site A.

Particularly in indirect control applications, repeaters using wireline often employ the use of DC signals to effect control. Such systems take advantage of the fact that audio-frequency signals can be superimposed on (and extracted from) DC-bearing lines without modifying the character of either the AC or the DC component. With such a system, the COR is positioned at the receiver (site B). Contact closure of the COR causes a B+ signal to be sent down the line along with the audio-frequency signals from the receiver. At the transmitter location (site A), the AC is picked off the line through a matching transformer whose centertap is comprised of a DC-blocking capacitor. The DC signal is used to trigger a current-operated relay to turn on the repeater transmitter. Figure 27-29 illustrates this scheme. If a second function is required, the direction of current flow could be reversed, and diode-selected relays used at the transmitter site.

Wirelines present special problems to the Amateur. One of the most noteworthy of these is maintaining an audio level which allows satisfactory operation without hum pickup, but which does not cause inductive crosstalk in adjacent lines. The simplest way to avoid trouble with "line neighbors" is to keep the level within the standards established by most telephone companies; that is, at a level which does not exceed + 1.0 dB above 1.0 milliwatt into a line with a 600-ohm termination (+ 1 dBm).

Determining actual dB level is a very simple process which can be accomplished with the aid of any good voltohmmeter which has an "output" range. Here's how: When the wireline has been installed, open the squelch at the receiver so that the normal squelch noise is fed continuously into the line. At the terminal point (transmitter location, site A), disconnect the line

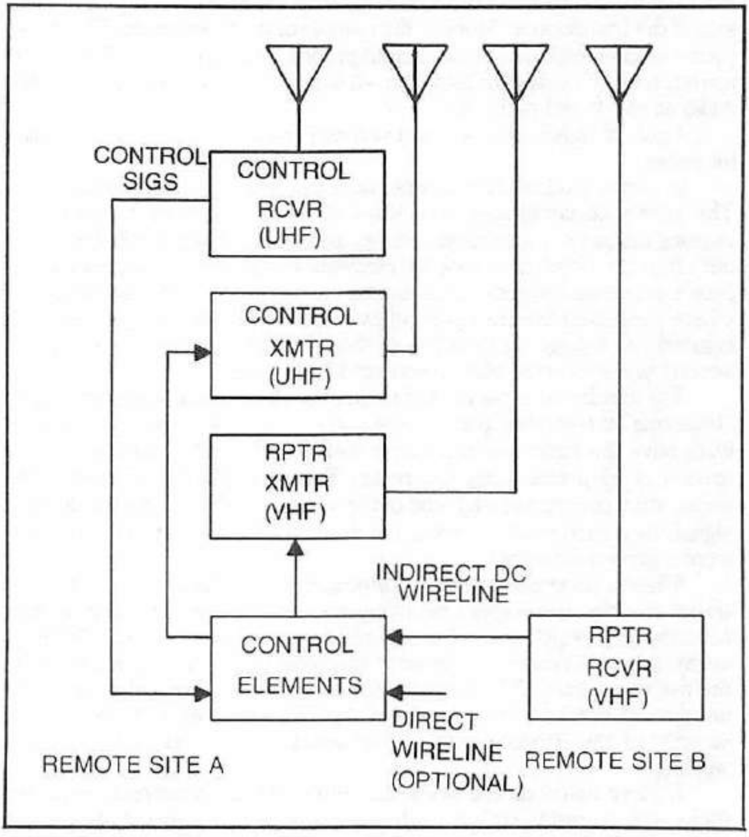


Fig. 27-28. Indirect wireline control system used for site interconnection.

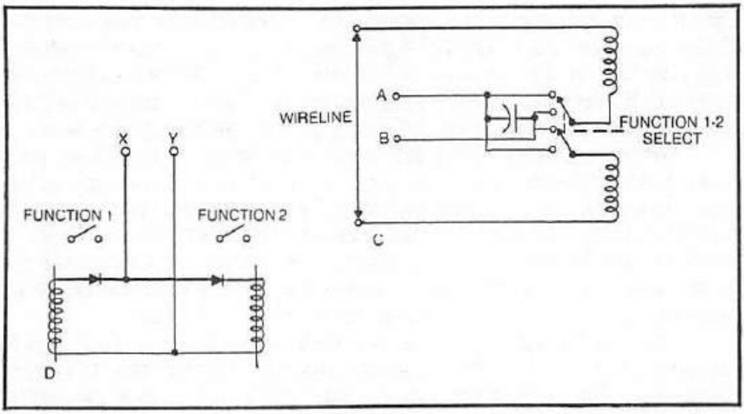


Fig. 27-29. Indirect wireline terminations.

from the transmitter and connect a 600-ohm resistor across it on the line side of the transformer. Monitor the reading of the noise on the dB scale of your voltohmmeter (AC mode, output probe). The level should be approximately 0 dB. If the level is less than −3.0 or greater than +1.0, reduce the audio at site B and recheck.

A pair of walkie-talkies, and a second person can make level setting a lot easier.

In some wireline installations, hum can become a serious problem. The telephone companies have ways of minimizing hum (for example, twisting the pair to cancel fields, phase cancellation at loop amplifiers, etc.), but often the problem cannot be eliminated entirely by the phone company's universal methods. One example of a typical "hard case" might be where the leased line traverses poles shared with high-voltage lines. The induced AC voltage on each line of the telephone pair can be as high as several hundred volts when referenced to ground.

The wireline user can further reduce the likelihood of hum problems by "balancing" the wireline pair. A wire pair is said to be balanced when both leads have the same resistance over their length and the same voltage to ground at all points along the route. Balancing can be effected in the termination circuitry at each end of the wireline by bypassing the dc input signals to ground and by keeping the dc input as well as the wireline away from a ground reference.

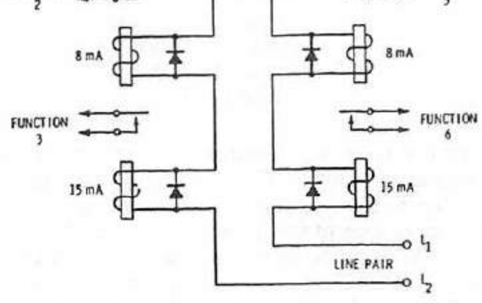
When a conventional line transformer is used (as in Fig. 27-29), the transformer itself provides a balancing method by virtue of the transformer coils through which each DC leg must pass. This method effectively negates the differences in resistance (to ground) at the DC input and allows the use of available DC voltages at the site (such as B + and ground). An unbalanced condition would exist if the DC signal were to be coupled directly to the wireline without the benefit of the series transformer winding.

If more functions are needed, in either direct or indirect operation, then current-sensitive relays can be used, along with polarity shifts. Careful planning will allow the selection of a number of functions so long as the sequence of selection is compatible with the functions selected. Figure 27-30 illustrates this concept, which uses polarized relays of differing current sensitivities to respond to functional commands. Diodes across the relay coils serve as the polarizing devices, as shown. Depending on the direction of the current on the line (L_1, L_2), relays from either the left bank or the right bank can be energized in sequence. (But relays from both sides cannot be energized at the same time.)

After selecting the bank and polarizing the line according to the table in Fig. 27-30, the control operator allows no more current than is necessary to pull in the most sensitive relay of the bank. To key the next function , the current, is increased to the point where the second relay pulls in. Function 1 may be keyed independently from function 2, and the right bank can be used without energizing the left (and vice versa); but the big disadvantage is that when a relay is energized on a given bank, all other lower-current relays on that bank will also be engaged. Thus, the functions for which this control system can be adapted are limited.

In practice, it is usually better to have no more than two relays on each bank, and select relays which have pull-in sensitivities that are at least 10 milliamperes separated, one from the other.

In the older T-1200 series Motorola DC wireline systems, the following DC currents and polarities were used.



FUNCTION	ACTION	RELAY CURRENT
1	L_1 · pos, L_2 · gnd	5 mA
2	L_1 · pos, L_2 · gnd	8 mA
3	L_1 · pos, L_2 · gnd	15 mA
4	L_1 · gnd, L_2 · pos	5 mA
5	L_1 · gnd, L_2 · pos	8 mA
6	L_1 · gnd, L_2 · pos	15 mA

NOTE: USE CURRENT-LIMITING RESISTORS AT LINE SOURCE

Fig. 27-30. Selection of six functions by controlling polarity and current level of transmitted DC signal.

State	Polarity	Current	Comments
Receive	(none)	0	speaker audio
Tx, F1	+	5.5 mA	on line
Tx, F2	+	10 mA	If single freq radio, F2 current used
.....	–	5.5mA	Mute second receiver (if present) Tx F2 to unmute
PL RX off to monitor	–	2 mA	Momentary function

AC wireline systems are a bit more complex, but the same basic principles are used. The information here is for a late-model Motorola system. There is one basic principle in AC systems, and that is that everything is done with tones. There is also a set of non-transmitting functions, such as frequency select, PL-mode select, receiver muting in a two-receiver system, etc. The basic technique is that a "guard tone" of 2175 Hz is sent down the line for 115 ± 5 mS, followed by a function tone for 35-40 mS. These function tones range from 650 Hz to 2050 Hz in 100-Hz steps. In the encoder, resonant reeds are used to obtain the guard tone, and L/C circuits for the rest. When a transmitting function is selected, operation is as described above, except that the function tone is followed by the guard tone at a low level (30 dB below the level that results in 5kHz deviation transmitter—a notch filter is used before the transmitter for the duration of the transmission. A list of sample function tones is shown below.

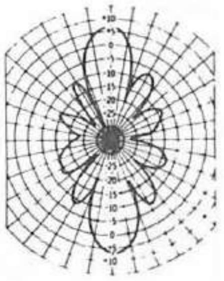
Freq.	Function
1950	TX F1
1850	TX F2
1750	Select F1 on RX, or mute RX # 2
1650	Select F2 on RX, or mute RX # 1
1550	Squelch maximum, RPT off or TX PL on
1450	Squelch minimum RPT on or TX PL off
1350	"Wild Card" # 1 on
1250	"Wild Card" off
1150	"Wild Card" # 2 on
1050	"Wild Card" off

Note that the only tone that is encoded during the transmission is the 2175 Hz guard tone and that at a low level. This permits the full range of single tones, alert tones, touchtones, paging tones, and the like to be transmitted with no degradation, except for the notch at 2175 Hz.

There is no reason why AC wireline techniques cannot be used on a radio system, and, if a set of AC wireline panels turns up at a swap meet, it might serve as the core of a versatile control system. These techniques could also be used, in a simpler fashion, on the cross-link of a split-site system.

Chapter 28

Touchtone Decoders and Techniques



The designers of most repeater-control systems have generally standardized on the Touchtone* system for their command transmission technique, and with good reason. The Touchtone approach has gained wide acceptance because of its inherent compatibility with existing telephone systems. Touchtone command signals are generated with a conventional Touchtone telephone dial which has an integral multitone encoder; this combination dial/encoder is referred to in the telephone industry as a "pad."

In the telephone service for which Touchtone was designed, two tones are dispatched to the central phone office for each digit selected. The lost time of waiting for the 10-pps pulse train after dialing of a digit is regained because the system does not require the sequential transmission of a single series of contact breaks as do old dial types. The ensuing enhanced reliability when applied to an amateur control system is readily apparent.

The Bell System's Touchtone equipment, as found in the consumer market, consists of eight discrete tone frequencies, arranged in a low and a high group, each of 4 tones. Sixteen digits can be represented by the combination of one tone from each group:

Low group		Consumer			Military	
697 Hz	1	2	3		A	Fo
770 Hz	4	5	6		B	F
852 Hz	7	8	9		C	I
941 Hz	*	0	#		D	P
High group		1209	1336	1477	1633	1633

It is not known whether the Bell system had "planned" on anything over and above the 4 x 4 matrix for Touchtone, but the 5 x 5 matrix in the 35xxx series pads suggests that they did. Any system should be designed to prevent any "non-standard" tones from being transmitted down the phone line, including the 5th row and column.

Another possibility for generating additional tones, or functions, is to switch crystals (if a chip-type pad is used) or switch capacitors (if an L-C type) and move the entire high or low tone group, or both. This will require additional decoders, but the security against "wrong people" gaining access to your system controls may be worth it.

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*Touchtone is a registered trademark of AT & T.

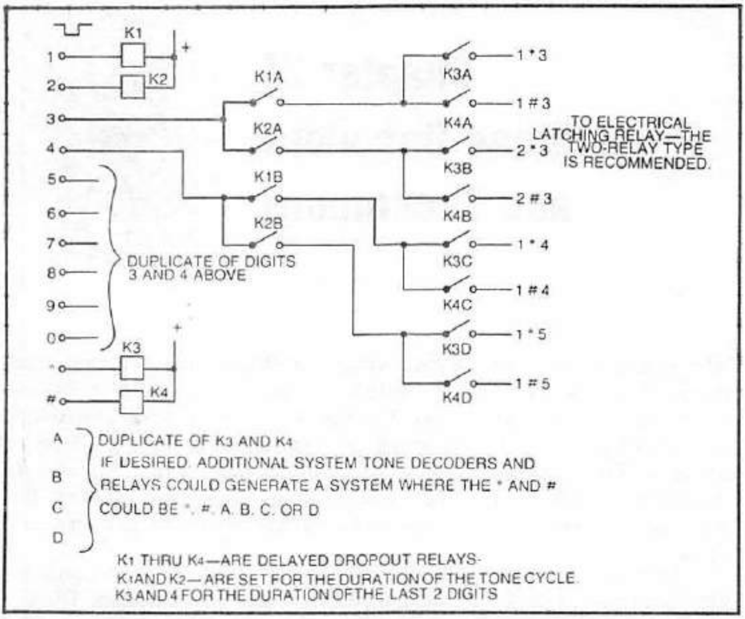

K1
1
2
K2
3
4
5
6
7
8
9
0
*
#
+
K3
K4
+
DUPLICATE OF DIGITS 3 AND 4 ABOVE
K1A
K2A
K1B
K2B
K3A
K4A
K3B
K4B
K3C
K4C
K3D
K4D
1 * 3
1 # 3
2 * 3
2 # 3
1 * 4
1 # 4
1 * 5
1 # 5
TO ELECTRICAL LATCHING RELAY—THE TWO-RELAY TYPE IS RECOMMENDED.
A
B
C
D
DUPLICATE OF K3 AND K4
IF DESIRED. ADDITIONAL SYSTEM TONE DECODERS AND RELAYS COULD GENERATE A SYSTEM WHERE THE * AND # COULD BE *, #, A, B, C, OR D
K1 THRU K4—ARE DELAYED DROPOUT RELAYS-
K1AND K2—ARE SET FOR THE DURATION OF THE TONE CYCLE.
K3 AND 4 FOR THE DURATION OFTHE LAST 2 DIGITS

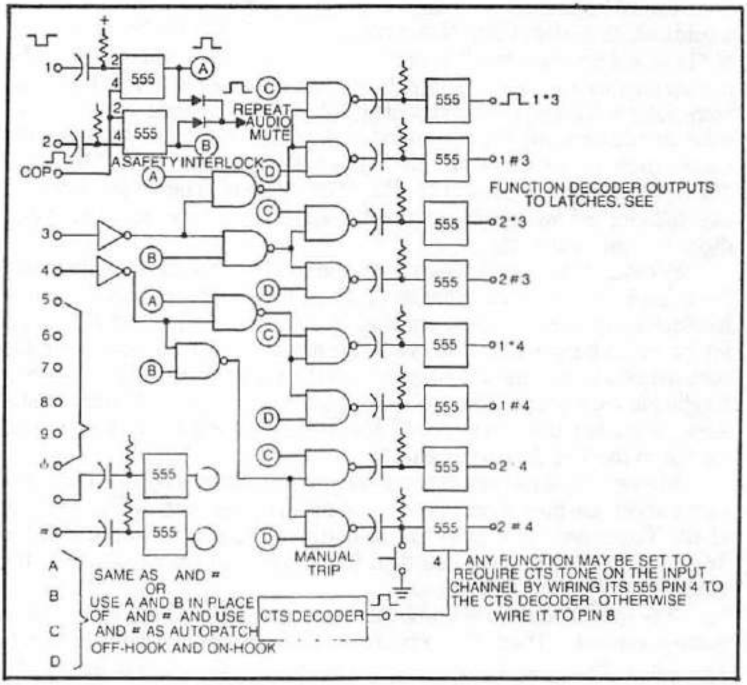
Fig. 28-1. Relay-type system-control decoder.

By this time, it has probably become pretty clear that Touchtone is a relatively complex approach in comparison to other control techniques in vogue. Completely ignoring the advanced technology of Touchtone and its compatibility with modern telephone systems, the system is highly versatile and has the potential of becoming a universal-control scheme, able to control anything from a remote location, with a useful subset available in any telephone (as soon as the nationwide Touchtone conversion is complete).

When remotely controlling a system, be it a repeater, a remote base, a hi-fi system with touchtone on an ultrasonic carrier, or anything, the control will probably take the form of sequential digits. Some form of "guarding" must be provided, since a button could be pressed accidentally, and we would want the logic to ignore such things. This is most easily done with timers. Another form of guarding can be done by limiting certain functions so that they cannot be initiated unless a certain CTS tone is present on the input or control channel.

An example of a simple relay-type decoding system is shown in Fig. 28-1 and a similar logic system in Fig. 28-2. Any of these systems can be expanded to a point, and then a redesign and/or rebuild will be necessary.

The remote-base owners learned long ago that this (the control system) is the most complex part of any system, and therefore should be expandable. For example, if you have a 2-meter open repeater, and that is all it is ever going to be (no links to other systems, etc.), you might be able to get away with a command format that is limited to 50 or 75 functions. However, most large systems use a format that allows at least 900 functions, usually more. A possible latch circuit is shown in Fig. 28-3.



+
1
2
COP
555
555
2
4
2
4
A
B
C
D
REPEAT
AUDIO
MUTE
A SAFETY INTERLOCK
3
4
5
6
7
8
9
*
#
1*3
1#3
2*3
2#3
1*4
1#4
2*4
2#4
FUNCTION DECODER OUTPUTS
TO LATCHES. SEE
MANUAL
TRIP
4
ANY FUNCTION MAY BE SET TO REQUIRE CTS TONE ON THE INPUT CHANNEL BY WIRING ITS 555 PIN 4 TO THE CTS DECODER OTHERWISE WIRE IT TO PIN 8
SAME AS AND #
OR
USE A AND B IN PLACE OF AND # AND USE AND # AS AUTOPATCH OFF-HOOK AND ON-HOOK
CTS DECODER

Fig. 28-2. Solid state system-control decoder.

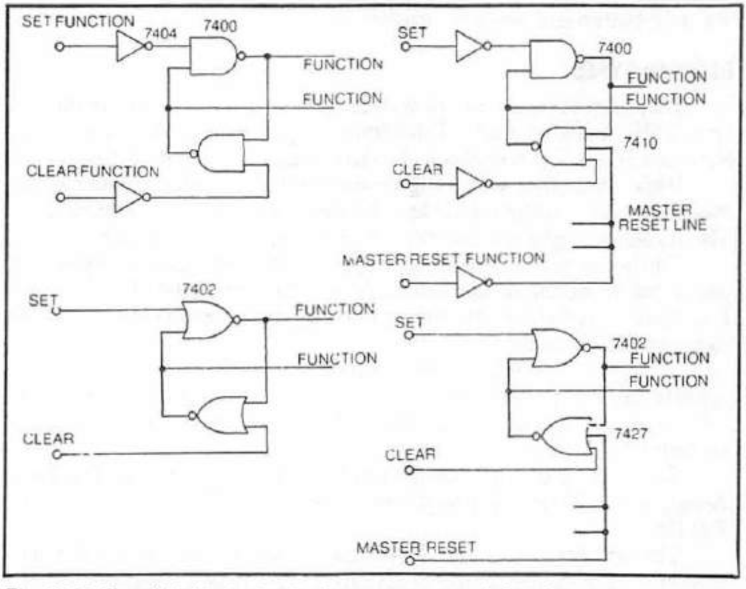


Fig. 28-3. Possible latch circuits for system-control decoder.

A word here about formats. A set of ground rules for a reliable system would include the following: Never repeat a digit. For example, a command of *12 would be okay, but *11, or **1 is not, and A1A would be okay. The reason for this is simple—flutter. If you had a system where *11 and *12 were valid functions, then functioning *12 while your signal was a little bit noisy and fluttery into the system could result in the system "hearing" any one or more of the following: *1, *11 (a valid function), *112, **1, **11, **111, *12 (the one we want) *2, **2, **22, *22, etc. The simple cure is to use self-clocked logic, without a digit counter, and to avoid all repeated digits in command strings.

Peculiar to the Los Angeles area, and to a lesser degree, Chicago and New York, is the small number of 12-button touchtone pads seen on handhelds, mobiles, and base stations. You see four to five 16-button pads for every 12-button one. Also, very few handhelds are purchase with the optional pads, since the optional pad is usually a 12-button job. The Heathkit handhelds are a prime example—the optional pads were 12-button units, since, according to a salesman, "There is no market for a 16-button pad, except in the Los Angeles area."

Maybe it is a false assumption, but it is the author's opinion that most ham's anticipate their future needs, and this, coupled with the facts that all of the Touchtone chips have the 16-button feature in them,and that the 16-button keyboards have less than $5 difference in price, influences the choice towards a 16-button pad.

Any specific system will probably start out as a "kerchunk box" with no remote controls. Then, the repeater on/off functions become remotely controlled. Then, maybe an autopatch is added to the system, and maybe WWV and Weather monitoring. If it is a 220 or 450-MHz system, a 2-meter radio may be hooked up as a remote base, and so on. By this time, the need for a 16-button pad becomes evident.

DECODER TYPES

There are several types of decoder in wide use, ranging from the ITT type 247B, found in many Touchtone telephone intercom systems, to Signetics 567-based homebrew decoders, and L-C based systems.

While the author was doing research for this book, he came across many different decoders, including the one in Ken Sessions' original book. The three most-popular decoders are presented in this section.

The home-built unit providing results, and incidentally the most-used one, is one designed by Alan Burgstahler, WA6AWD, around 1975. It is an L-C based unit, and uses the 88mH toroids, which are very common in the Amateur RTTY world.

This unit is incredible—the author has listened to a system using it operate flawlessly when the user's signal was 90% noise, and the user's voice could not be understood. And, to the author's knowledge, the unit has no history of falsing.

One user of that particular system deliberately runs his Touchtone deviation at ± 500 Hz, with no trouble. Normal CTS tone deviation is 500 to 750 Hz.

The 567 decoder in Fig. 28-4 is the classic one that was in the older Signetics data sheets. Many people have built it and complained that it

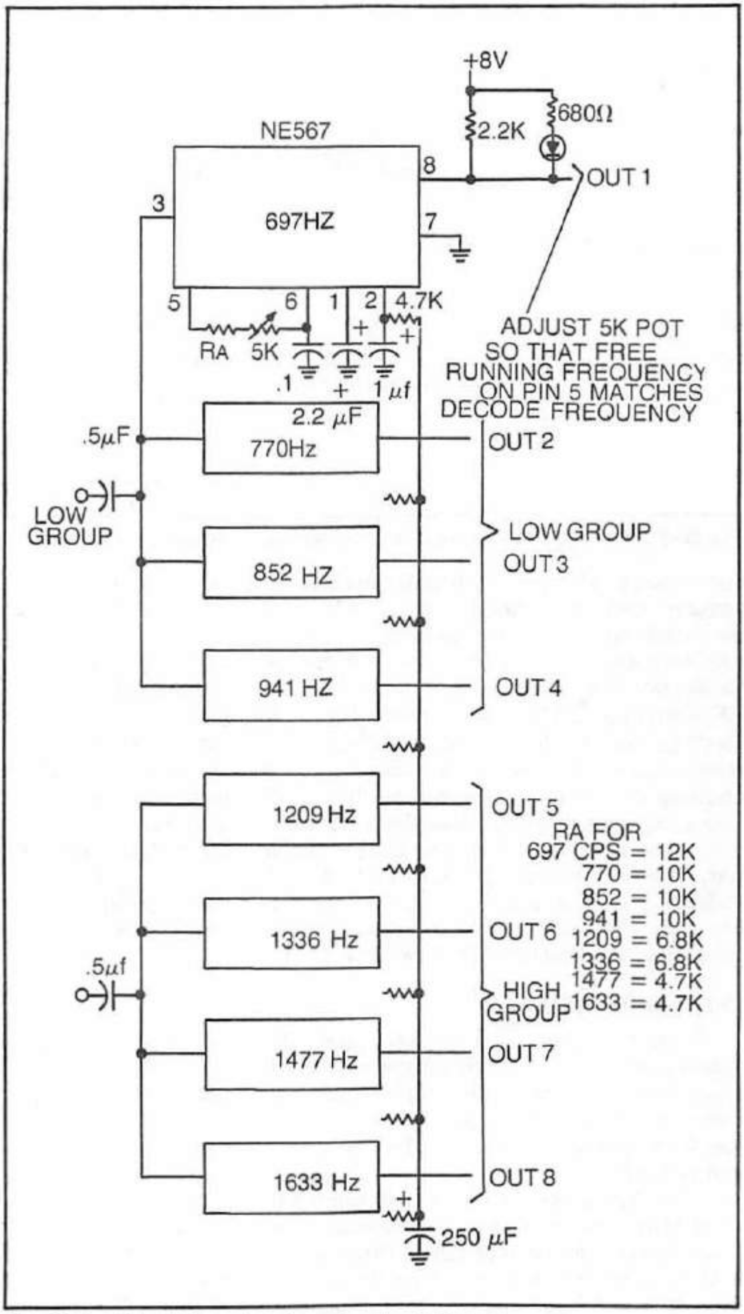


Fig. 28-4. A Touchtone decoder using the NE567 IC.

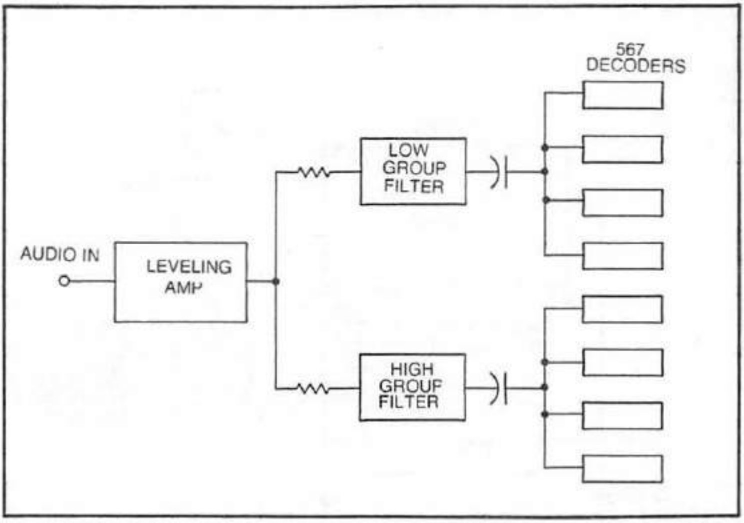


Fig. 28-5. A leveling amplifier improves the reliability of the circuit of Fig. 28-4.

doesn't work. The reason is that the unit was designed to meet telephone-company standards, where the tone level is 4 times the voice level. When the sensitivity (ie, the decode level) is turned up to where it decodes a touchtone level of 3-kHz deviation (i.e. radio use), the unit has a tendency to false on voice. Other complaints have been that the unit "folds up" in an RF environment. There is not much that can be done about that except shield the decoder. If your decoder folds up when you run your transmitter during system construction, it is obvious that there is a defficiency in the shielding somewhere, either around the decoder, or in the transmitter. One group is using a 567-based decoder, with a 741-based, active-filter-type group filter card; the whole thing is built inside a Bud, Inc. die-cast box, with feed-through capacitors on each lead. Some of the NE567 decoder problems can be alleviated by the use of a leveling amplifier ahead of the group-filter circuit, if that circuit does not already provide it. An example of this technique is shown in Fig. 28-5.

THE WA6TPR SYSTEM

This control system, Fig. 28-6, is currently in use in at least four Los Angeles machines. It's a 12-button system, although it could be easily expanded to 16. One of the unique features about this system is that it allows one, two, or three-digit functions. Therefore, you could reserve * and # for autopatch, yet have 1x for one set of functions, 2xx for another, and so forth.

One handy, but almost never-thought-of function, is a nice creature-comfort item: In one nearby system, there is a switched pair of AC outlets. A large electric heater is plugged into one of them, and can be turned on an hour in advance of a site visit. When the work crew gets there, the shack is nice and warm! Also, see Figs. 28-7 through 28-16 and Tables 28-1 through 28-5.

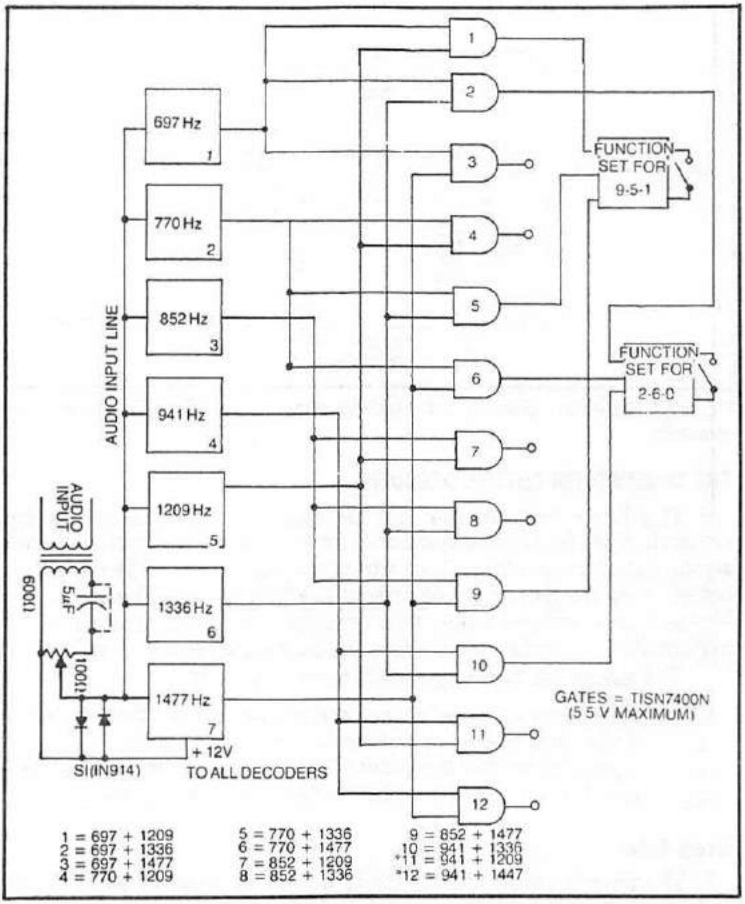


Fig. 28-6. The WA6TPR decoder system.

Table 28-1. Parts list for seven decoders and matrix.

7—Toroids 88mH
4—10k pots Mallory MTC 14L1
3—50k pots Mallory MTC 54L1
1—100 ohm pot Mallory MTC 12L1
3—TI SN7400N quad 2 input NAND gates
3—IC sockets TI 014ST-7519
1—120 ohm 2w resistor
7—100 ohm ¼w resistor
4—22k ¼w resistor
4—10k ¼w resistor
4—270 ohm ¼w resistor
7—2.2 k ¼w resistor
4—.047 μF 100V 225P orange drop
7—1μF, 15v Sprague 500D
7—Germanium diodes

2—Silicon diodes (1N914)
4—2N3638 (PNP silicon)
7—WEC 1 (NPN silicon)
7—Sets of capacitors for frequency adjustment. (see below)
2—Circuit boards
2—22 pin pc card sockets

Approximate Values

697 - .597μF
770 - .503μF
852 - .412μF
941 - .337μF
1209 - .192 μF
1336 - .158 μF
1477 - .134 μF

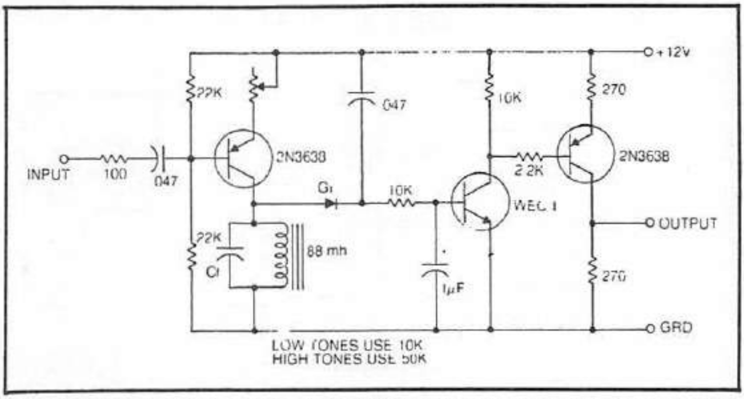


Fig. 28-7. Schematic diagram of the individual decoders in Fig. 28-6. Seven are required.

THE WA6AWD TOUCHTONE DECODER

This is the best decoder that the author has come across during research either for his own system, or for this book. Now, that is a pretty strong statement, but then, this is a pretty strong decoder. The unit is L-C based, using the 88 mH toroid popular in RTTY circles. The author has listened to a system using this decoder, and been amazed at its performance—decoding tones when the user signal was 90% noise.

The author has two suggestions for this decoder:

1. *Perform the setup and alignment of this decoder exactly as described, if you want maximum performance from this decoder.*
2. *If you discover that the output is "upside down" from what you need, U5, U6, U7, and U8 can be replaced with 7432 gates.*

Group Filter

The filter board in the system is the Group Filter, Fig. 28-17. It operates from plus and minus 15 VDC and has a 600-ohm audio input. The 88-mH toroid and the two 1-μF non-polarized capacitors form a high-pass filter rolling off at about 300-cycles, which limit the effects of PL or AC hum on the group filters. After being amplified, the audio is split into two sections and is filtered by the networks prior to U2 and U3. The network

Parts List For Function Board
(2 Function)

28—WEC 1 (NPN silicon)
4—.22 μF 75V orange-drop capacitors 225P
2—Reed relays 12v (Electronic applications 1A12A)
6—100K ¼w
12—1K ¼w
4—2.2k ¼w
4—10k ¼w
1—circuit board
1—22 pin PC-card socked
4—silicon diodes (1N914)

Table 28-2. Parts list for function board.

prior to U2 band-rejects the high-group tones and the network prior to U3 band-rejects the low-group tones. After the audio is filtered and amplified by U2 and U3 it is clipped hard by the diodes on the output of the two amplifiers. The diodes are needed to keep the audio outputs at a constant level, which keeps the bandwidth of the tone decoders constant. If the windings on the 88-mhy toroids have not been tampered with, and the capacitors used to tune them are ± 10 % or better, no tuning of the toroids is necessary to make the Group Filter work correctly.

To set up the board for proper operation, insert a 600-Hz tone, full-system-deviation signal into the receiver which will feed the decoder system. With that signal being fed into the input of the Group Filter board, connect an oscilloscope to the test point on the board and adjust the

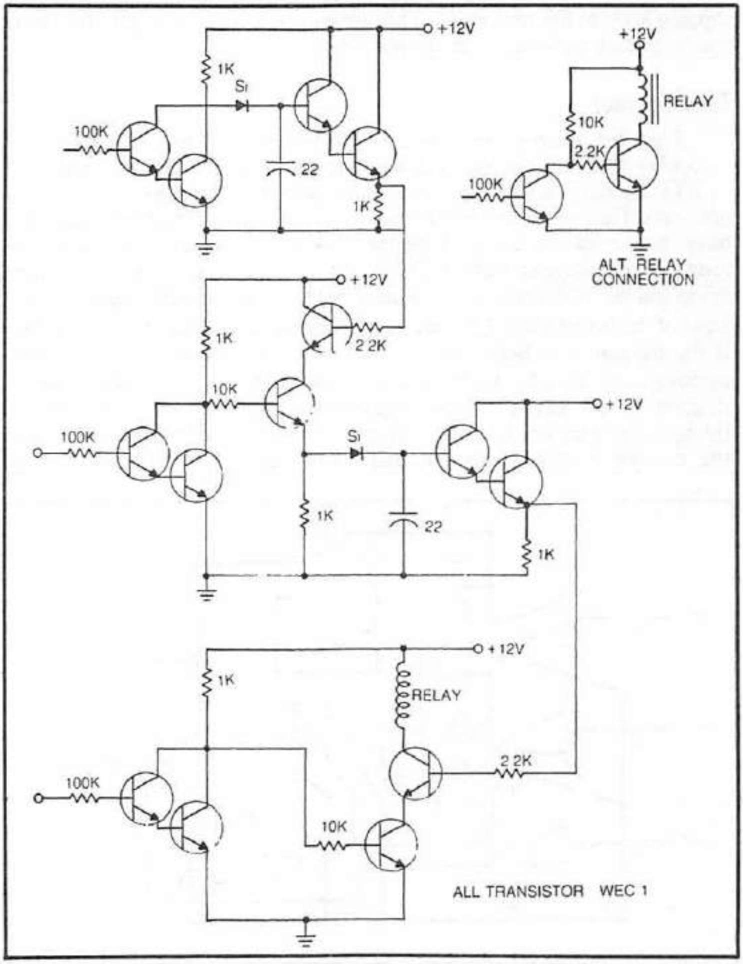


Fig. 28-8. Function section schematic. Two required per card.

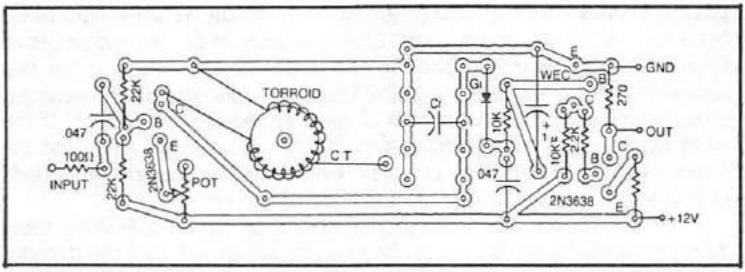


Fig. 28-9. Decoder foil pattern and parts layout, foil-side view.

500-ohm pot until the audio signal seen on the scope is just below the clipping level at the test point. This allows the Touchtone system to have the maximum audio-level range possible.

Tone Decoder

The next board is the Tone Decoder board, Fig. 28-18. It operates on +15 VDC and, with the zener diode on the output, is compatible with DTL or TTL logic (pulls low when tone is present, pulls high when tone is not present). There are four tone decoders on each circuit from the main audio buss that feeds the board. With the 25-k pot set at approximately mid-range, and a scope or audio VTVM connected at the junction of the signal diode and the 10-k resistor on the base of Q2, insert an audio signal into the input of the board and determine at what frequency the tuned circuit peaks. If the frequency is below the desired center frequency of the decoder, remove turns from the toroid until the resonant frequency is the frequency desired. *Do not* cut the wire from the toroid until you are sure that those are the number of turns you wish to remove. If the resonant frequency is above the desired center frequency, add some turns to the toroid until the

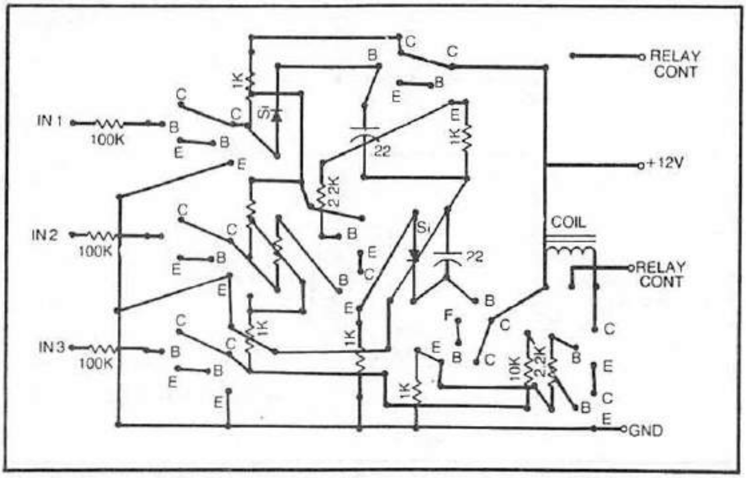


Fig. 28-10. Function foil pattern and parts layout, foil-side view.

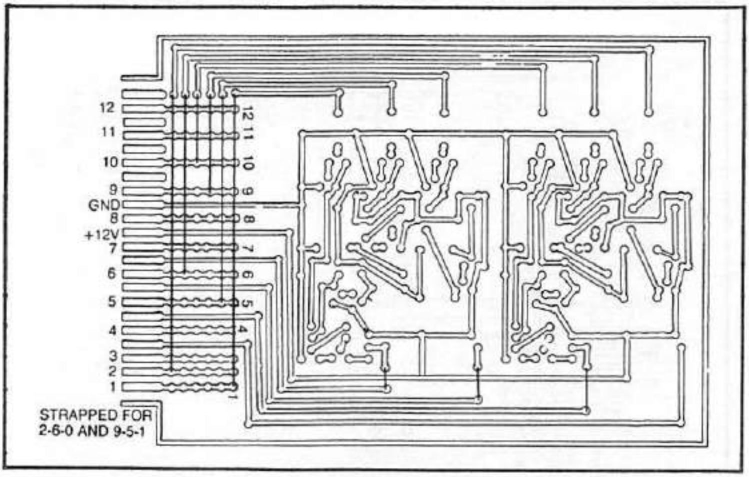


Fig. 28-11. Function card foil pattern, foil-side. See Fig. 28-10 for parts placement.

resonant frequency is the frequency desired. The capacitors used to tune the toroid should make the frequency fall relatively close to the desired frequency. Once the toroids have been tuned to frequency the decoders must be set for the proper time delay. It has been found that a delay of 35-milliseconds is about the proper amount of delay between the time that the tone has entered the decoder and the time that the output signifies that the tone has been decoded. This eliminates most falsing of the decoders

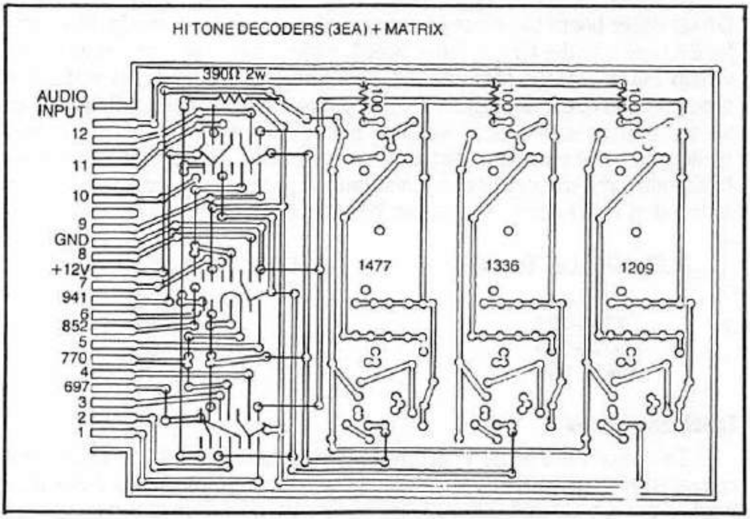


Fig. 28-12. High-tone decoder card foil pattern. See Fig. 28-9 for parts placement.

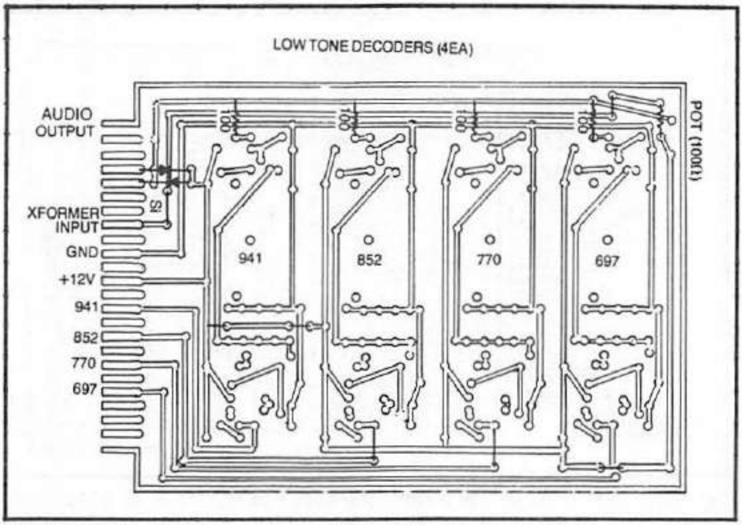


Fig. 28-13. Low-tone decoder card foil pattern. See Fig. 28-9 for parts placement.

on voice and other noises, but gives a quick decoding time for the desired tones. With a scope connected to the output of the decoder to be tested, and set to trigger upon receipt of a tone on the input of the decoder, check the amount of time it takes to decode the tone. If the time is more or less than 35 mS, adjust the value of the 500k trimpot until the time is 35 mS (± 5 mS). Do this to each decoder. Once the timing of the decoders has been accomplished, it is necessary to adjust their bandwidth. With the specific Group Filter board to be used feeding both high- and low-group decoders, feed a tone into the Group Filter board, making sure that the output of the Group Filter board is hard clipped when the tone frequency is within the tone group in question. Adjust the 25k pot on each decoder until the output shows that it is decoding within a bandwidth of ± 2% of its center frequency. An easy way to do this is to set the tone frequency for the upper bandwidth limit frequency and adjust the 25k pot until the output just shows a decoded (low) state. The upper frequency limits are shown below.

LOW GROUP TONES	HIGH GROUP TONES
697—711	1209—1233
770—785	1336—1363
852—869	1477—1507
941—960	1633—1666

Touchtone Matrix

The next board is the Touchtone matrix board, Fig. 28-19. This board converts the logic outputs of the Tone Decoders into the actual digits that were sent. ICs U3 and U4 are BCD-to-decimal decoders that ensure that only one tone has been decoded out of each of the high- and low-tone groups. The Tone Decoder logic is fed into U3 and U4 as individual data bits

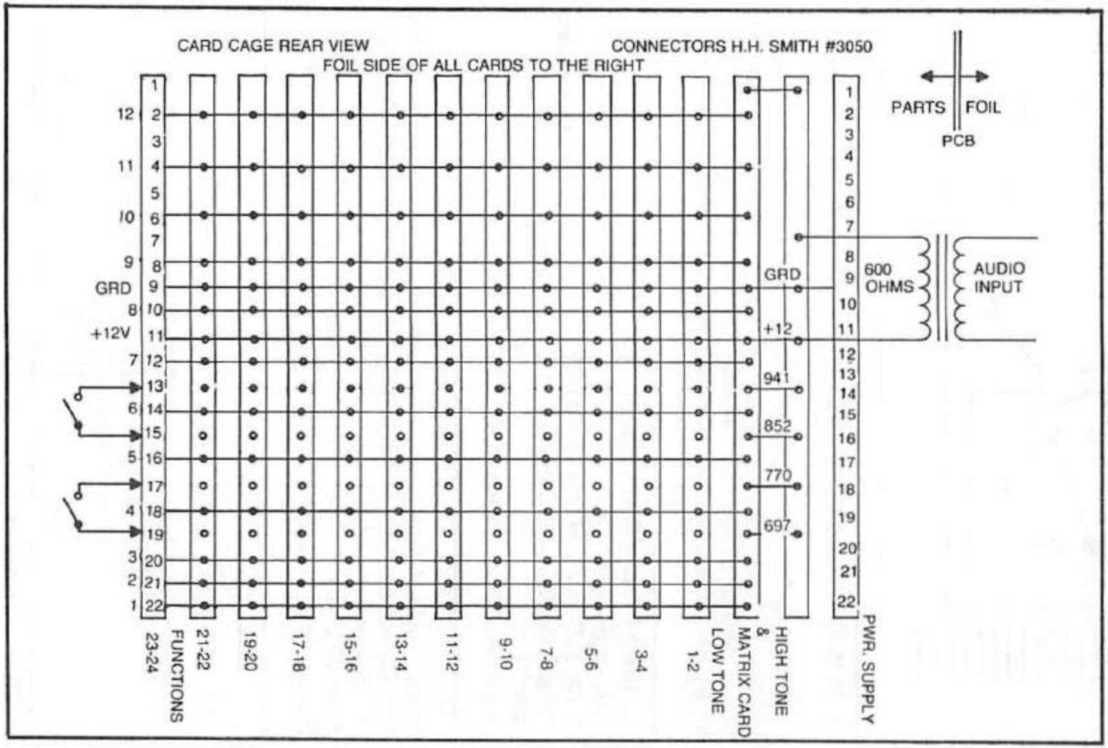


Fig. 28-14. Card-cage connections.

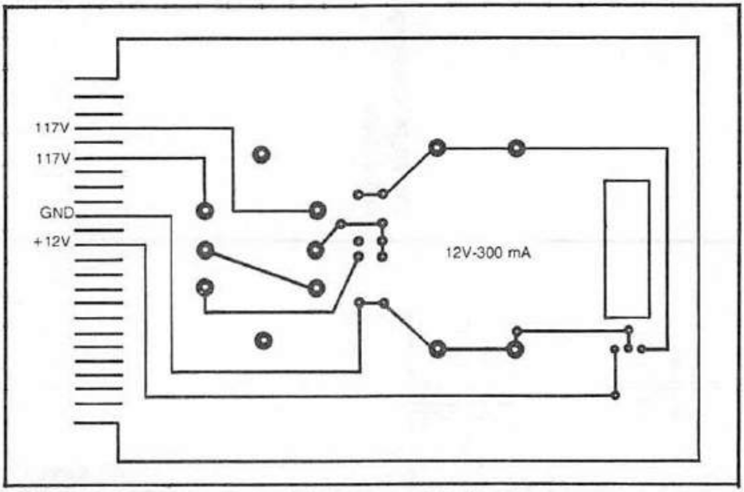


Fig. 28-15. Power-supply card, foil pattern, foil-side view.

of a BCD group, and the outputs are taken off of the decimal equivalents of the binary inputs. If two tones in a group happen to decode at one time, the BCD-to-decimal decoders add the binary values of the inputs and activate the decimal output of the particular binary input combination. That decimal output would not correspond to a normal single tone in that group being decoded, and the result is that there would be no output from the Matrix card. For instance, the logic from the 697-Hz tone decoder is fed into the chip in the binary 1 position and fed out of the chip in the decimal 1 position. The logic from the 770-Hz tone decoder is fed into the chip in the binary 2

1-TRIAD F-142 XP XFORMER
4-Si Diodes 50V-1A
2-1000μF-25V CAPS (TVA-1211)
1-Fairchild MGH 7812 REG.
1-PCB
1-22 PIN EDGE CARD SOC.

Table 28-3. Parts list for power supply.

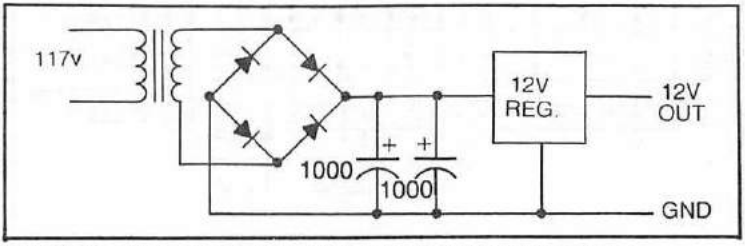


Fig. 28-16. Schematic diagram of a power supply for the decoder.

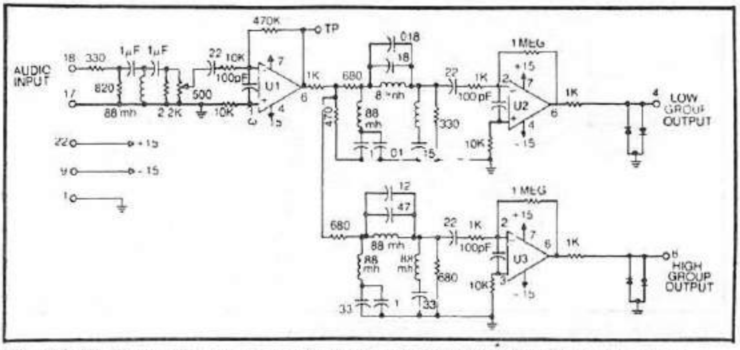


Fig. 28-17. Group filter schematic for the WA6AWD Touchtone decoder.

position and fed out of the chip in the decimal 2 position. The 852-Hz logic is on binary 4 and decimal 4, and 941-Hz logic is on binary 8 and decimal 8. If the 697-Hz and the 852-Hz tones should decode simultaneously, there would be a logic input on binary 1 and binary 4 which would produce an output on decimal 5. However, since there is nothing connected to the decimal-5 output, the rest of the matrix would see no tone logic from the low tone group and, regardless of whether there was a high tone decoded or

Table 28-4. Tone-decoder parts list.

Group Filter
Parts List
Resistors ¼-Watt
2 - 330 ohm
1- 470 ohm
3 - 680 ohm
1 - 820 ohm
5 - 1k ohm
1 - 2.2k ohm
4 - 10k ohm
1 - 470k ohm
2 - 1-megohm

1 - 500 ohm trimpot

Capacitors
3 - 100pF disc

Orange-Drop Capacitors 100V
1 - 01 µF
1 - 018 µF
2 - 1 µF
1 - 12µF
1 - 15 µF
1 - 18 µF
3 - 22 µF
2 - 33 µF
1 - 47 µF
2 - 1-µF non-polarized capacitor

7 - 88 mH toroid

4 - Silicon diode

3 - LM307 IC

TOUCHTONE MATRIX
PARTS LIST
16 - 1k ohm ¼watt resistor
16 - 470 ohm ¼watt resistor
2 - 01µF capacitor disc
2 - 1µF capacitor disc
16 - NPN switching transistor
2N697 2N1711 2N2219 2N2222 or equiv
2 - 7400 IC
4- 7402 IC
2 - 7442 IC

TONE DECODER
PARTS LIST
Resistors ¼ Watt
4 - 120 ohm
4 - 1.0k ohm
4 - 2.2k ohm
8 - 10k ohm
4 - 22k ohm
4 - 47k ohm
4 - 68k ohm
4 - 220k ohm
4 - 100k ohm

4 - 25k ohm potentiometer
4 - 500k ohm potentiometer

4 - 0.1 µF 100V Sprague Orange-Drop capacitor
4 - 0.47 µF 3V disc ceramic capacitor
4 - 5 or 10 µF 6V electrolytic capacitor
4 - signal diode
4 - 5.1V 400 mW Zener diode (1N751)
4 - 88 mH toroid
16 - NPN small signal transistor (2N5134 2N2221 or equiv.)
4 - PNP small signal transistor (2N5138 2N5067 2N2907 or equiv.)

Capacitors 100V Orange-Drop

Used on the LOW GROUP board only

1 - 0.018 µF
1 - 0.068 µF
1 - 0.12 µF
2 - 0.33 µF
2 - 0.47 µF

Used on the HIGH GROUP board only

1 - 0.01 µF
2 - 0.015 µF
1 - 0.018 µF
1 - 0.1 µF
1 - 0.12 µF
1 - 0.15 µF
1 - 0.18 µF

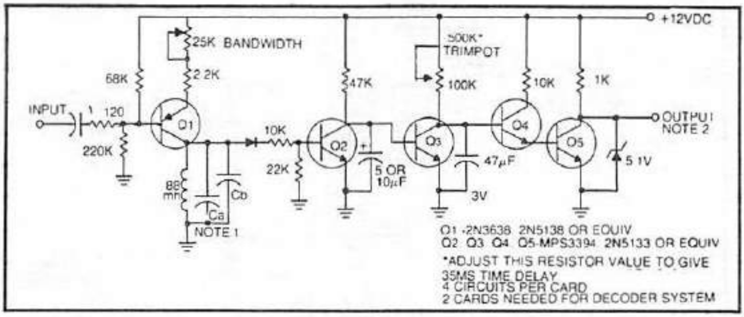


Fig. 28-18. Tone decoder for the WA6AWD system.

not, the matrix would give no output on any digit. ICs U5 through U8 decode the high and low tone decoder logic into 16 outputs corresponding to the buttons of a 16-button touchtone pad. Transistors Q1 through Q16 are high-current drivers to drive succeeding logic. The collector of each transistor sits at 5 VDC, and pulls low when its particular digit is decode. If

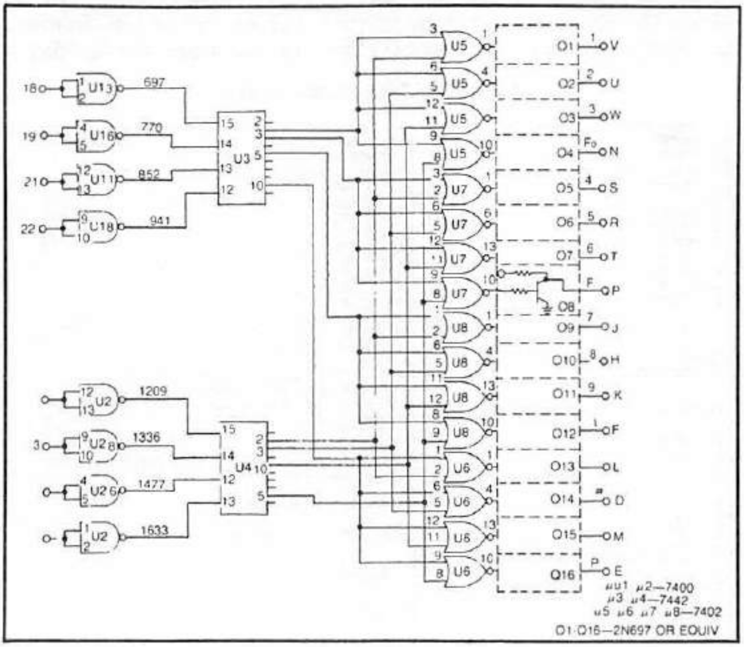
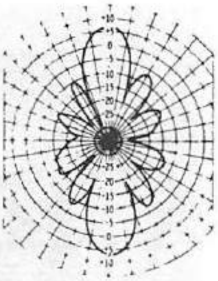


Fig. 28-19. The Touchtone matrix diagram for the WA6AWD system.

2N697 transistors are used in the output, and we assume a maximum collector current of 500 mA, each output has a fanout of 300. Other transistors may be used, and their fanout can be milliamperes by 1.6.

$$\frac{\text{max collector current in mA} = \text{fanout}}{1.6}$$

Chapter 29
Autopatch



The autopatch system described here is designed for use in areas with Touchtone dialing. Since rotary dialing is fast becoming a thing of the past, inclusion of that system in this part of the book was deemed irrelevant. However, if your central office has not yet been converted to Touchtone dialing, you will need some form of Touchtone-to-rotary dialing converter. A unit of this type can be built using the Motorola MC 14419 & MC14409 integrated circuit chips. Data on these devices is available from Motorola Semiconductor Products Division, Motorola Corporation, 3501 Ed Blaustein Boulevard, Austin, TX 78721.

AUTOPATCH COUPLER

Again, we turn to K6PUW for this device. Over the years, there have been many autopatch coupler designs presented to the amateur public. However, most, if not all, have had one significant drawback: They were designed with the radio, rather than the telephone, in mind. That is to say, virtually all of the couplers lacked any real working telephone-type of interface, and few paid any attention to telephone-company line and dialing requirements. Most designs have tried to interface "low-band" phone patching equipment to radio remote-control dialing. Most of these schemes work. However, very few amateurs are aware how little margin exists. See Fig. 29-1.

In radio, we normally consider 3 kHz a maximum tone deviation, and 4.5 to 5 kHz a peak voice deviation. While this might lend itself to radio control, the telephone line hates these levels with a passion. Actually the telephone touch-tone decoders want to hear 10 dB more audio on dialing tones than they do on voice transmission. This is done to prevent false dialing. However, most autopatch designs fail to take this important difference into consideration, and many Amateurs wonder why their personalized, super-spiffy autopatch design performs more like a nightmare.

The design presented in this section is simplicity itself, yet it is designed to perform the duties of a desk telephone—by radio remote control. In essence, that is what your autopatch coupler must be able to do. It should totally emulate every aspect of the telephone company's own instrument, since such devices were engineered to work with the telephone system.

The K6PUW Autopatch Coupler is actually three sections, see Fig. 29-2. First is a Touchtone decoder interfaced to operate the relay logic of

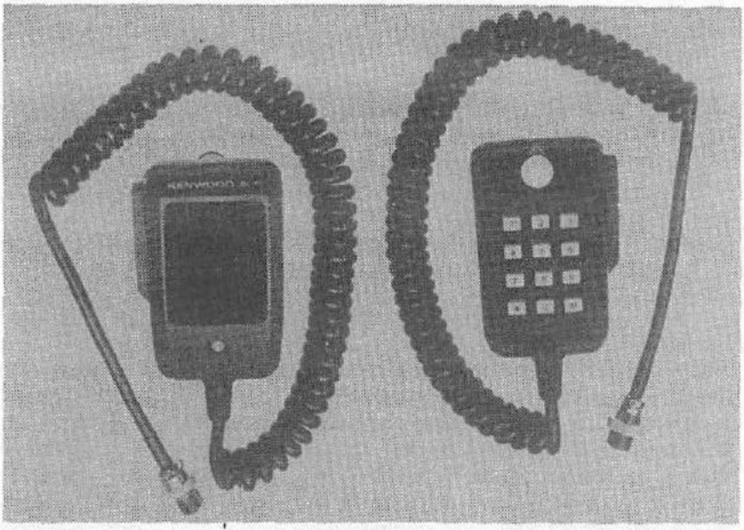


Fig. 29-1. The modern way to work through an autopatch system is to use a microphone with built-in tone pad (courtesy of Trio-Kenwood Communications).

the dialer portion of the coupler. Second is the coupler itself, which permits the telephone line to see and hear exactly what it is accustomed to seeing and hearing. The final item is an option for systems that wish to have a "reverse-autopatch" or "dial-in" feature. This last item is the "air ringer." Since there are many differing types of decoders available, the only prerequisite here is that the decoder be made to present the proper voltage to actuate relay K-1 each time a digit is dialed. K-1 is the tone-level-increase relay. K-2 is the "off hook" relay, which connects the patch to the telephone line. Interface of these two relays is left to the system designer.

The heart of the unit is an Automatic Electric WA1155A line-matching network from an Automatic Electric Telephone, exactly the same type of unit a normal telephone has in it. You purchase from Automatic Electric (or one of their distributors/retailers) an Automatic Electric telephone, and strip the part you want from it. It cannot be purchased separately. In addition, no other brand of line-matching network has been found to perform well in this circuit, due to impedance differences between manufacturers. Obtaining this exact part is critical to the overall performance of this coupler.

Note: Do not under any circumstances tamper with or remove parts from any telephone-company-owned equipment. To do so is a violation of Federal law and you can be subject to fine, imprisonment or both. Purchase your phone through an authorized Automatic Electric retail or wholesale outlet only.

T-1, in Fig. 29-2 is a Motorola audio transformer, type 25C8599121. It couples audio from your receive-audio buss to the AE Line Matching Network, through the normally closed contacts of one section of K-1. R-1 is the input level adjustment to the network. Audio is applied to the network between pins 5 (high side) and 23 (low side). Audio to the transmitter

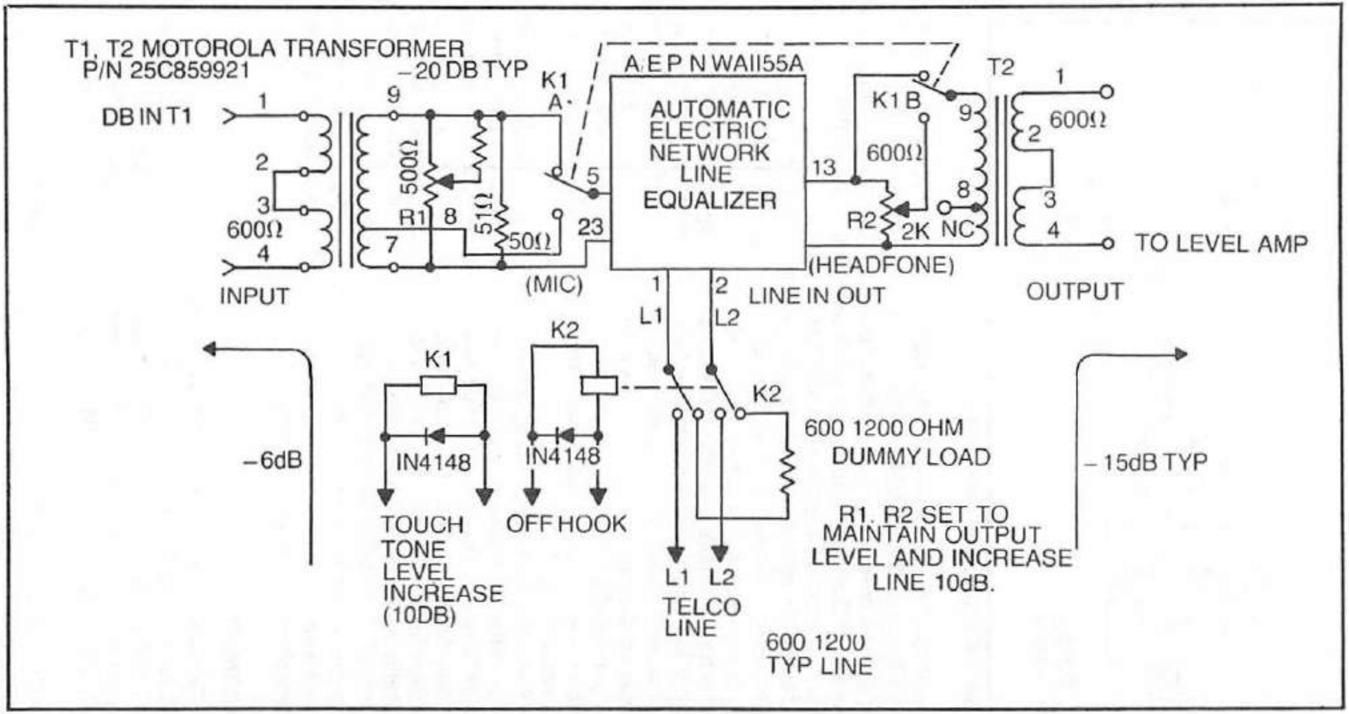


Fig. 29-2. The K6PUW autopatch interface.

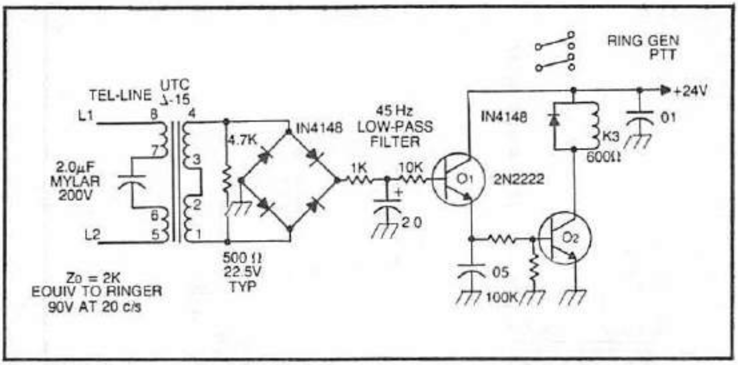


Fig. 29-3. A ringer simulator/detector.

passes through the network and exits at pin 13, where it is coupled through another Motorola 25C859921 transformer to the transmit mixer. Note that this coupler is never switched out of the audio line. K-2 acts to connect the phone line to the coupler during autopatch time, and connects the coupler output to a constant impedance at all other times.

During the dialing sequence, a voltage derived from the "any digit" logic line in your decoder package is used to close relay K-1 while a digit is being dialed. With K-1 actuated, tone level from the receiver's recovered audio is boosted approximately 10 dB before entering the telephone line. Resistor R-2 is provided to reduce this level 10 dB before it passes to the transmit audio mixer, so as to reduce any "blasting" effect of tones on the retransmitted audio. If you do not wish to retransmit tones, an additional relay paralleled with K-1 can be added in the transmit-audio line, and its normally open contacts used to mute transmit audio when a dialing sequence takes place.

A few words about the construction of this coupler: It should be noted that no common ground connection exists. This is because the coupler actually "floats," with pin 23 of the line matching network used as a common tie point. Do not ground this point to. the chassis or you will introduce unwanted hum and noise. The coupler itself should be built in a steel or aluminum enclosure, and kept completely enclosed and shielded for both AF and RF. The enclosure itself can be grounded to the system, however, the actual internal wiring should use only pin 23 of the line-matching network as its common return tie point. This affords total isolation between the telephone line and the system itself.

ADJUSTMENT

Adjustment is simple and straight forward. R-1 is adjusted to place input audio 10 dB below tone level. Adjust this while monitoring across L1-L2 with a scope, and no phone line connected to the coupler. R-2 is then adjusted to reduce tone output to the transmitter audio mixer by the same 10 dB. Due to the way K-1 b is wired, this control has no effect on normal voice.

The optional "dial-in" ringer, Fig. 29-3, is also a K6PUW design, and is again a simple yet foolproof unit. If the coupler simulated the audio section

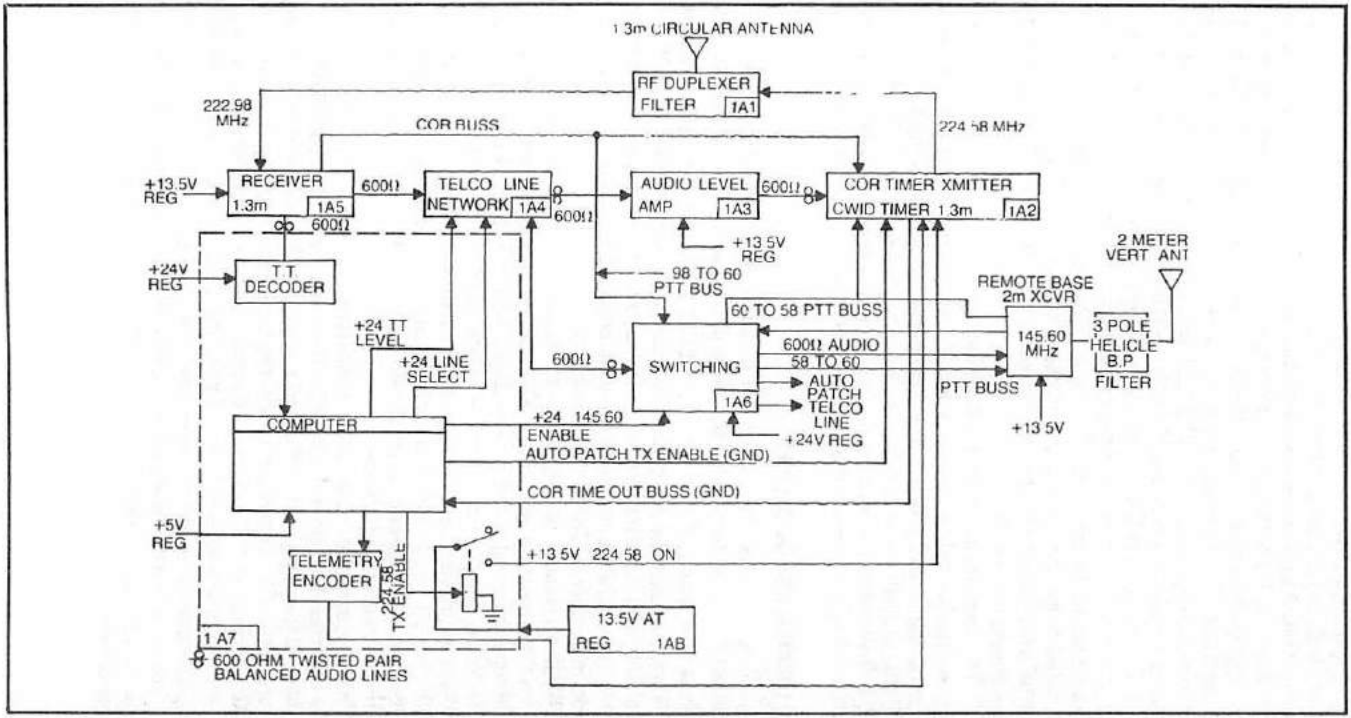


Fig. 29-4. System block diagram of the WA6VNV repeater, with the shaded area showing autopatch interfacing.

of a telephone instrument, then the ringer simulates the telephone instrument's bell. In fact, the primary of a UTC-A-15 transformer is wired to do exactly that. As far as the telephone line is concerned, it sees a bell. Ring voltage is coupled to the secondary of the transformer and rectified to DC, then applied through a 1k ohm resistor to charge the 2 μF, 150 V electrolytic capacitor. The discharge path is through the 10k ohm resistor and the emitter-base junction of the 2N2222A transistor, Q-1. This transistor is emitter-coupled to a second 2N2222A (Q-2) that serves as a relay driver for K-3. The contacts of K-3 can be used to activate an audio oscillator fed into the transmit-audio mixer and to place the transmitter on the air should the phone ring. In this unit, only the connections marked L-1 and L-2 must be insulated from the system grounding. Once past the bridge rectifier, a normal grounding technique can be used in construction. 2N2219s can be substituted for the 2N2222As.

The coupler and ringer just described are currently in use on a number of Los Angeles and San Diego repeaters, and each has reported excellent results. Audio quality both ways is excellent, no dialing falsing occurs, and the ring-in feature is a delight. The system block diagram is shown in Fig. 29-4. *Remember, always have the local telephone company install a coupling device before you connect this or any other device to your phone line.*

AUTOPATCH USE GUIDELINES

While on this subject, let me mention the following guidelines for autopatch use, derived from the rules and regulations as of this writing.

1)It is a violation of Part 97 of the FCC Rules and Regulations to use Amateur Radio for any pecuniary interest. This includes autopatch and phone patching of business calls. If you have any doubt about the content of your call falling into that grey area, either do not make the call or hang up immediately. Don't risk a pink slip.

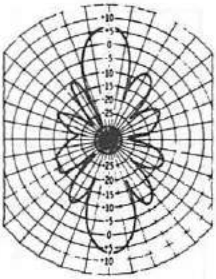
2)While a repeater is engaged in autopatch operation, a system control operator must be monitoring. The concept of "Open User Responsible" autopatch operation has never existed, according to the FCC in a "Notice of Rules Clarification" released in late 1978. Either a control operator must be present, or the ability of a patch to function must be defeated by the license or his assigned control stations. Operation of autopatch on systems that operate under the doctorine of "Full Time Automatic Remote Control" is forbidden.

3)While operational in autopatch configuration, a repeater is not considered a repeater, but rather it falls under the category of an individual Amateur base-station radio. Therefore, all rules governing base-station operation are applicable, in addition to the repeater rules and regulations.

4)It is a violation of Federal law to connect any device to the telephone line without providing some form of FCC and Telephone Company approved protective device to the telephone line. Do not do this yourself. Such "couplers" must be installed by the local telephone company, and there is a fee for this service. Failure to comply with this law carries severe penalties.

Chapter 30

Time and Timers



Timers are used in repeaters and remote bases to do many things, both obvious and obscure. An obvious application is to drop the repeater carrier if a user talks too much; this is called the timeout timer. A not-so-obvious use is to delay the transmitter B+ turn-on until the tubes have warmed up after a power outage. Timers can also be used for such purposes as connecting and disconnecting phone patches, energizing identification systems, disabling control systems, and a variety of other functions, many of which may not appear to involve "time" as a critical (or even necessary) element.

The work "timers" is a general term used to describe many different types, and in this chapter, we will try to clear up some of the mysteries.

CHOOSING A TIMER

The first step in selecting a timing circuit, is to identify the type of delay you need. Although the various delay types are known by a flock of different names, there are only three basic types.

Delayed Activation

The timer trigger signal "turns on," and after the preset delay, the output becomes active, see Fig. 30-1. Note the word active—the trigger may be a low-to-high transition, or a high-to-low, and the output may be either. The individual characteristics will be whatever the circuit designer had in mind, but the basic characteristics will be the same no matter what the individual circuits' voltages are. A repeater timeout timer is an example of this type; when the output becomes active it inhibits the transmitter.

Delayed Release

The timer trigger signal is in the active state, and the output is also active, Fig. 30-2. The trigger input changes to the inactive state, and the time period starts. At the end of the period, the output returns to an inactive state. Note that the input inactive-to-active transition has no effect on the timer action, except to cause the output signal to follow. An example of this form of timer is a repeater's hang-in timer.

Interval Timer

The timer trigger input changes from the inactive to the active state, which causes the output signal to go active, and starts the timing process.

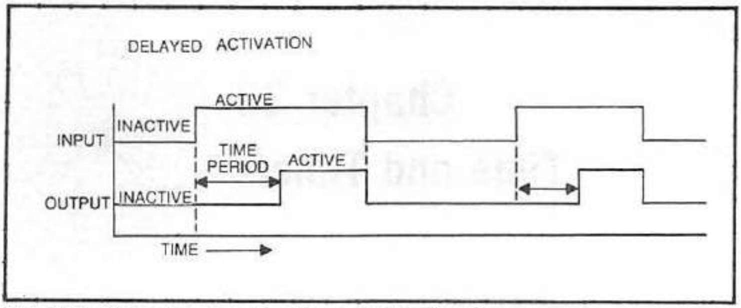


Fig. 30-1. Time diagram of a delayed-activation timer.

At the end of the time period, the output returns to the inactive state. The trigger input is usually ignored once the timing cycle starts, see Figs. 30-3 and 30-4. The active-to-inactive transition is also usually ignored. The "beep" duration timer is an example of an interval timer.

One major assumption is made in the above discussion: the power to the timers is constant, with no noise to cause false triggering. For example, a power loss during the cycling of almost any timer would affect its operation, unless, a very old and very reliable type were used, such as the pneumatic timer.

Most timers fall into one of four major categories:

- Thermal—(Similar in appearance to vacuum tubes.)
- Pneumatic
- Motorized
- Electronic—(Most commonly used in new designs.)

Of all the above, the thermal timer is probably the least accurate, and exhibits the worst repeatability. These characteristics are not always drawbacks in certain applications, such as delaying application of B plus to a given circuit, or an entire system, until the tubes are warm.

The thermal delay relay is an inexpensive device incorporating a thermostatic element as its functional mechanism. The heating element "warps" a bimetallic strip. The time the strip takes to warp sufficiently to make the contacts open or close is the delay time. Thermal delays are usually small enough so that a great many can be mounted on a single

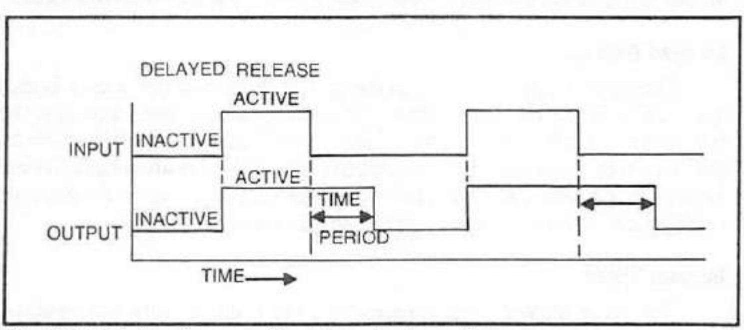


Fig. 30-2. Timing diagram of a delayed-release timer.

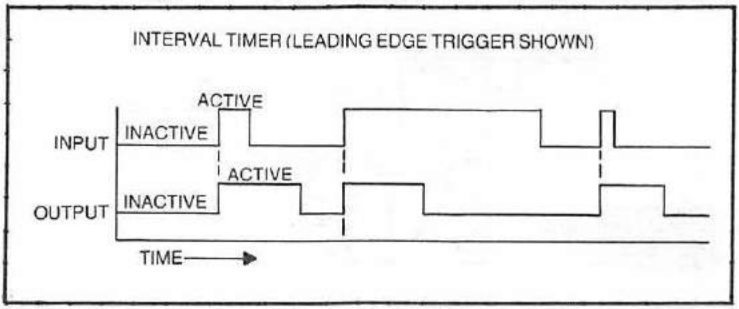


Fig. 30-3. Timing sequence of an interval timer with leading-edge triggering.

chassis or panel. They can be purchased with standard pins to match conventional miniature or octal tube sockets.

The chief disadvantages of the thermal delay are excessive recovery time between operations, and heavy current requirements. A thermal timer energized too soon after a previous use will cause premature switching of the function that is to be delayed because the bimetallic strip has not fully cooled. These units are well suited for any application where a delay is required, but it's length has a loose tolerance, and where a large cycle-to-cycle variation is not important.

Many pneumatic timers aren't much better, some having repeatabilities in the 25% to 50% range. The few good pneumatics around come with a starting price of over $50, new. These devices employ a variable-tensity pressure diaphragm that provides positive action after the specified period.

Motorized timers are basically a clock designed to mechanically activate one or more sets of electrical contacts through an electro-mechanical clutch or cam mechanism. At one time, not long ago, motorized timers had the capability of being the most accurate and repeatible form of non-electronic timer. Reset was accomplished mechanically by de-clutching the motor from the contact mechanism, which in turn was then returned to the "0," or rest, point by a self-contained spring. Only recently did one of the first Los Angeles area major repeater groups replace their motorized time-out timer and pneumatic hang-in timer with modern electronic timing devices. Another Los Angeles system, K6MYK, now WR6ABN, still uses pneumatic timers and has since its inception.

One of the earliest forms of electronic timer used a device known as the Unijunction Transistor, or UJT. An example of such a device is the 2N2160. With the advent of modern IC Timers, the UJT timer circuit has

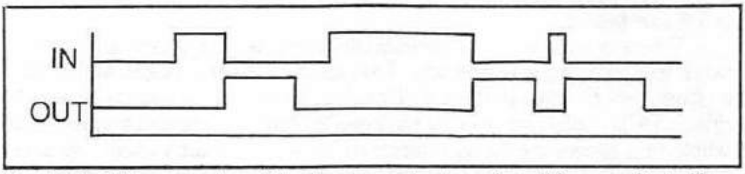


Fig. 30-4. A timer can invert the input or output, as does this one with trailing-edge triggering.

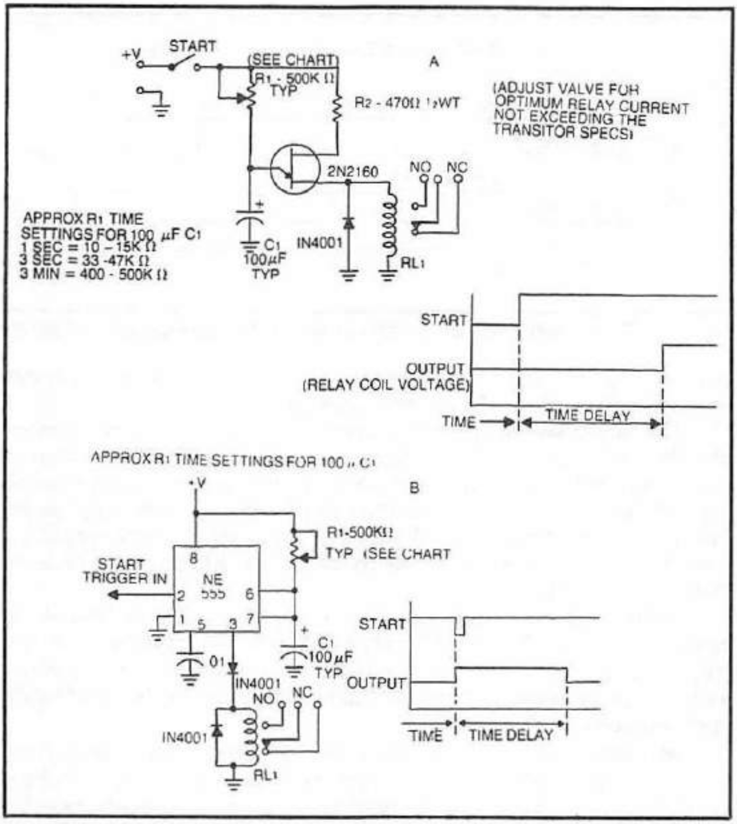


Fig. 30-5. A typical UJT timer circuit, A, and an NE555 IC timer, B, showing timing sequence after trigger input.

been all but forgotten. This is unfortunate in that there are a number of applications wherein the UJT circuit is simpler and cheaper than the equivalent IC timer circuit. A comparison of a UJT circuit *vs* an IC timer circuit is shown in Fig. 30-5.

The electronic timer, and the 555 in particular, offers the best performance for the electronic experimenter and Amateur builder. Accuracies of ± 10 % or better are common, and repeatabilities of ± 2 % are not unusual with inexpensive parts. Good polystyrene capacitors, metal-film resistors, and mil-spec ICs can get the accuracy down to ± 2 %, and repeatability to ± 0.5 %, or better.

Where accuracies and repeatabilities are really important, an approach taken by a local group is practical. They used a 100kHz crystal, and divided its frequency down to 10 Hz and 1 Hz rates. These pulses were then used to drive a BCD down-counter that had been loaded with a preset number. The whole unit allows the hang-in timer to be set, by thumbwheel switches, from 0.1 to 9.9 seconds in 0.1 second steps. The timeout timer can be set from 000 to 999 seconds, in 1 second steps. The particular unit is all CMOS.

While this approach is a bit extreme for hang-in and time-out timers, it does offer both high accuracy and easy "thumbwheel" adjustment of the timing intervals involved.

The time range of the timer circuit is important to the application—you obviously wouldn't use a circuit that would require a 10,000 μF capacitor for a 3-minute timer if a different circuit was available that could use a 100 μF capacitor. Equally important are accuracy and repeatability—two similar yet different characteristics. Accuracy defines the tolerance within which the timer must operate—5 % tolerance on a 5 minute timer is 15 seconds. Repeatability is the maximum variation in the time period between one operation and any other. Let's say that our hypothetical 5 minute, 5 % timer has a 2 % repeatability. The 5 % accuracy figure would allow our timer to meet specifications if it operated between 285 and 315 seconds, *ie*, 5 %. The 2 % repeatability would allow it to operate over a range of 6 seconds, from 285 to 291 seconds, or 295 to 301 seconds, or even 308 to 314 seconds, but the spread between repeated operations would never be greater than 6 seconds.

If a choice must be made of one over the other, it would be wise to choose repeatability, since in most system applications, the actual time period is not too important—a hang-in timer doesn't have to be 5.000 seconds, but if it were to vary from 4 seconds on Monday noon to 7 or 8 seconds Tuesday night, to 3 seconds on Friday, it would get to be alittle annoying, unless it was done deliberately. One contributing group has used a thermistor as the timing resistor of their hand-in timer. By comparing the interval of the hang-in timer timer to a previously drawn chart, they know the approximate system ambient temperature. Instant telemetry at no extra cost!

As you design your control system, you will see that timers of one form or another are indispensable. Where you cannot afford to take chances by depending on your repeater users to manually perform the necessary switching functions, and where there is a likelihood that "command" control may not at all times be capable of being achieved, you will find timers to be the answer.

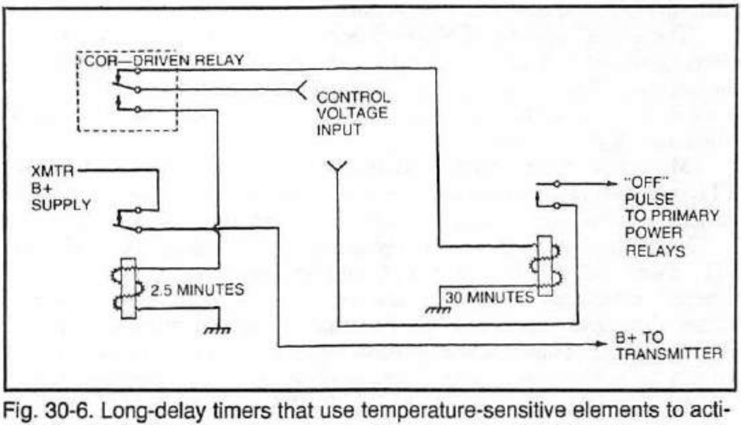


Fig. 30-6. Long-delay timers that use temperature-sensitive elements to activate the contacts.

There are a great many very common uses for passive timer control. Figure 30-6 for example, is a circuit that uses two timers to perform a dual control function: that of (1) shutting off the transmitter B+ supply when an input transmission exceeds two minutes, and (2) shutting down the transmitter (or repeater) completely when it has not been used for a period of one-half hour.

CMOS CONTROL

The 555 timer chip, coupled with TTL logic, has caused more advances in control-system circuitry in recent years than anything else.

CMOS logic has the potential of causing another revolution in control system design, due to the following advantages:

- It will run on anything from 3 to 15 volts, and therefore can use almost any existing supply.
- It is essentially RF proof.
- It is low power—a TTL system was replaced with a much larger CMOS system yet the current drain went from 6 A to 500 mA.
- CMOS is more versatile. There are several chip functions available in CMOS that could not be built in TTL because the complexity would result in overheating inside the chip package. Things such as 1′ stage counters, variable 1-to-64 bit shift registers, 4 × 4 cross-point audio switch with control memory, etc.

If a totally new system is going to be designed, the authors suggest that it be a CMOS system. The reference manuals from National Semiconductor, RCA, Motorola, Fairchild, and Ti should be acquired. While one might be enough to get started, each manufacturer has unique devices that might suggest a different, easier way to do something. Be careful—don't use devices that are not readily available. One TTL system that the author is aware of does not use 74279 quad flip-flops—the designer used 7400s back-wired into flip-flops, just to make sure that when one blew, he'd have a spare available, at the local Radio Shack, if necessary.

The author hopes that CMOS will become more popular—it has a lot to offer, is not overly expensive, and the only thing holding it back is a fear of the unknown. Too many designers are comfortable with TTL, and because it will do everything that they need, they say "why should I have to learn a whole new logic system?"

Most of the circuits published later in this book are TTL—not because TTL is better, but because they were designed years ago, before CMOS became popular. Converting any of them to CMOS is not difficult.

No matter how far the authors go in citing the advantages CMOS over TTL, there will still be many TTL and 555-based timer circuits constructed, maintained, extended, and improved upon by their builders. Rather than fight this trend, we feel that we should provide as much information as possible using this technology. Much of the following material has been excerpted, with permission, from several publications by Signetics Corporation, a subsidiary of U.S. Phillips Corp., 811 E. Arques Ave., Sunnyvale California 94086. Please be aware that many of these

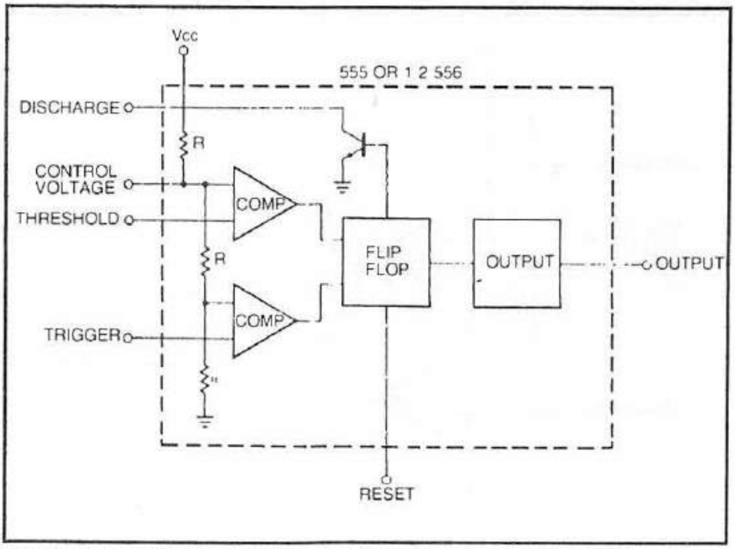


Fig. 30-7. Functional block diagram of the Signetics NE555/556 timer IC.

manufacturer-provided publications are of limited circulation and are not commonly available.

Description

The 555 timer consists of two voltage comparators, a bistable flip-flop, a discharge transistor, and a resistor divider network. To understand the basic concept of the timer let's first examine the timer in block form as in Fig. 30-7.

The resistive divider network is used to set the comparator levels. Since all three resistors are of equal value, the threshold comparator is referenced internally at 2/3 of supply voltage level and the trigger comparator is referenced at 1/3 of supply voltage. The outputs of the comparators are tied to the bistable flip-flop. When the trigger voltage is moved below 1/3 of the supply, the comparator changes state and sets the flip-flop driving the output to a high state. The threshold pin normally monitors the capacitor voltage of the RC timing network. When the capacitor voltage exceeds 2/3 of the supply, the threshold comparator resets the flip-flop which in turn drives the output to a low state. When the output is in a low state, the discharge transistor is "on", hereby discharging the external timing capacitor. Once the capacitor is discharged, the timer will await another trigger pulse, the timing cycle having been completed.

The 555 and its complement, the 556 Dual Timer, exhibit a typical initial timing accuracy of 1 % with a 50ppm/°C timing drift with temperature. To operate the timer as a one shot, only two external components are necessary; resistance and capacitance. For an oscillator, only one additional resistor is necessary. By proper selection of external components, oscillating frequencies from one cycle per half hour to 500 kHz can be realized. Duty cycles can be adjusted from less than one percent to 99 percent over

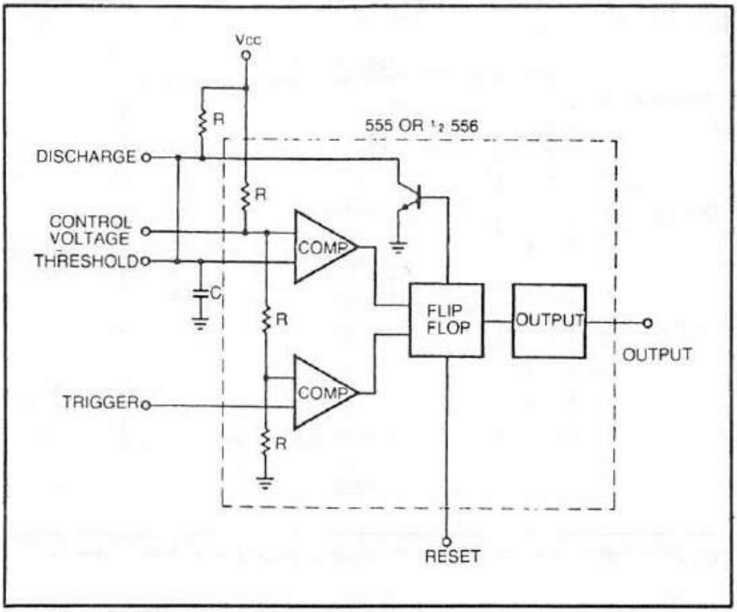


Fig. 30-8. NE555 in monostable operation.

the frequency spectrum. Voltage control of timing and oscillation functions is also available.

Monostable Operation

The timer lends itself to three basic operating modes:

1. Monostable (one shot)
2. Astable (oscillatory)
3. Time delay

By utilizing any one or combination of basic operating modes and suitable variations it is possible to utilize the timer in a myriad of applications. The applications are limited only to the imagination of the designer.

One of the simplest and most widely used operating modes of the timer is the monostable (one shot). This configuration requires only two external components for operation (see Fig. 30-8). The sequence of events starts when a voltage below one third Vcc is sensed by the trigger comparator. The trigger is normally applied in the form of a short negative going pulse. On the negative going edge of the pulse, the device triggers, the output goes high and the discharge transistor turns off. Note that prior to the input pulse, the discharge transistor is on, shorting the timing capacitor to ground. At this point the timing capacitor, C, starts charging through the timing resistor, R. The voltage on the capacitor increases exponentially with a time constant T = RC. Ignoring capacitor leakage, the capacitor will reach the two thirds Vcc level in 1.1 time constants or

$$T = 1.1\ RC$$

where T is in seconds; R is in ohms and; C is in Farads. This voltage level trips the threshold comparator, which in turn drives the output low and turns on the discharge transistor. The transistor discharges the capacitor, C, rapidly. The timer has completed its cycle and will now await another trigger pulse.

Astable Operation

In the astable (free run) mode, only one additional component, Rb is necessary, see Fig. 30-9. The trigger is now tied to the threshold pin. At power up, the capacitor is discharged, holding the trigger low. This triggers the timer, which establishes the capacitor charge path through R_A and R_B. When the capacitor reaches the threshold level of 2/3 Vcc, the output drops low and the discharge transistor turns on.

The timing capacitor now discharges through R_B. When the capacitor voltage drops to 1/3 Vcc, the trigger comparator trips, automatically retriggering the timer, creating an oscillator whose frequency is given by:

$$f = \frac{1.49}{(R_A + 2\,R_B)\,C}$$

Selecting the ratios or R_A and R_B varies the duty cycle accordingly . Lo and behold, we have a problem. If a duty cycle of less than fifty percent is required, then what? Even if $R_A = 0$, the charge time cannot be made smaller than the discharge time because the charge path is $R_A + R_B$ while the discharge path is R_B alone. In this case it becomes necessary to insert a diode in parallel with R_B, cathode toward the timing capacitor, Fig. 30-10. Another diode is desirable, but not mandatory, this one in series with R_B, cathode away from the timing capacitor. Now the charge path becomes R_A,

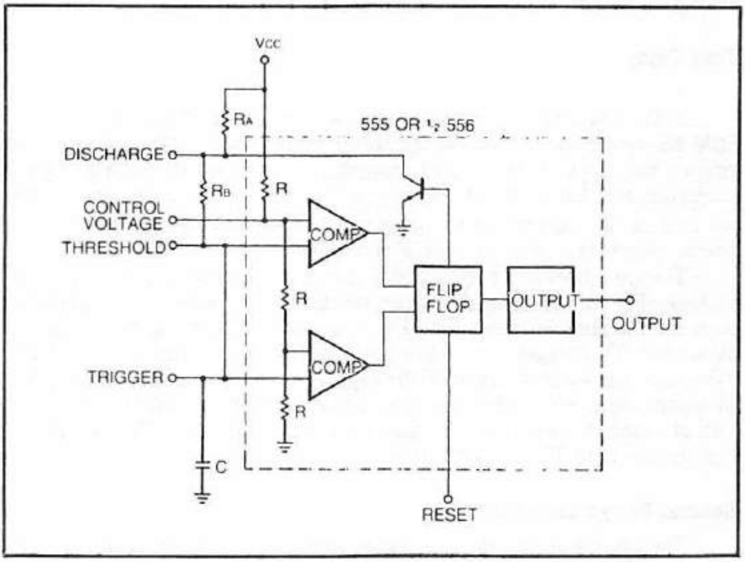


Fig. 30-9. NE555 in astable operation.

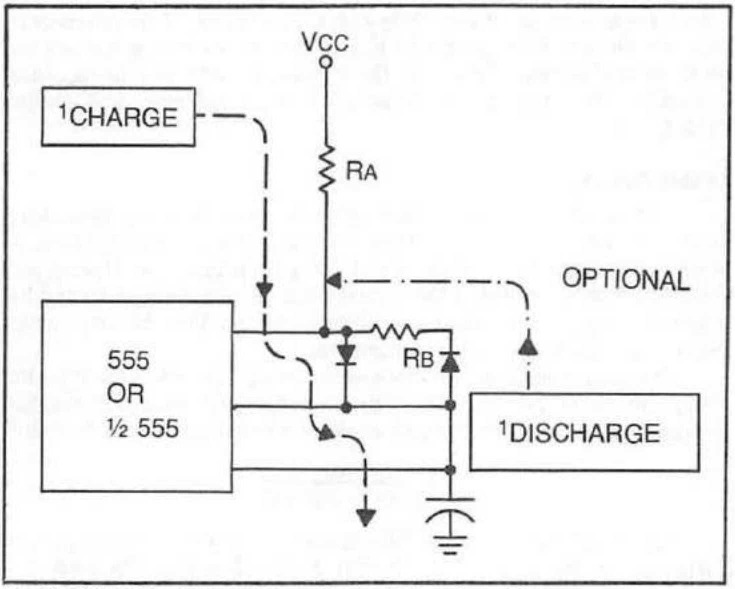


Fig. 30-10. Method of obtaining duty cycle less than 50%.

through the parallel diode into C. Discharge is through the series diode and RB to the discharge transistor. This scheme will afford a duty cycle range from less than 5 % to greater than 95% . It should be noted that for reliable operation a minimum value of 3K Ω for RB is recommended to assure that oscillation begins.

Time Delay

In this third basic operating mode, we aim to accomplish something a little different from monostable operation. In the monostable mode, when a trigger was applied, the output immediately changed to the high state, timed out, and returned to its pre-trigger low state. In the time delay mode, we require the output not to change state upon triggering, but at some precalculated time after trigger is received.

The threshold and trigger are tied together monitoring the capacitor voltage, Fig. 30-11. The discharge function is not used. The operation sequence begins as transistor (T1) is turned on, keeping the capacitor grounded. The trigger sees a low state and forces the timer output high. When the transistor is turned off the capacitor commences its charge cycle. When the capacitor reaches the threshold level, then and only then does the output change from its normally high state to the low state. The output will remain low until T1 is again turned on.

General Design Considerations

The timer will operate over a guaranteed voltage range of 4.5 volts to 15 volts DC, with 16 VDC being the absolute maximum rating. Most of the devices, however, will operate at voltage levels as low as 3 VDC. The timing interval is independent of supply voltage since the charge rate and threshold level of the comparator are both directly proportional to supply. The supply voltage may be provided by any number of sources: however, several precautions should be taken. The most important, the one which provides the most headaches if not practiced, is good power supply filtering and adequate bypassing. Ripple on the supply line can cause loss of timing accuracy. The threshold level shifts causing a change of charging current. This will cause a timing error for that cycle.

Due to the nature of the output structure, a high power totem pole design, the output of the timer can exhibit large current spikes on the supply line. Bypassing is necessary to eliminate this phenomenon. A capacitor across the Vcc and ground, ideally, directly across the device is necessary. The size of capacitor will depend on the specific application. Values of capacitance from $.01\mu$F to 10μF are not uncommon. Note that the bypass capacitor would be as close to the device as physically possible.

Selecting External Components

In selecting the timing resistor and capacitor, there are several considerations to be taken into account.

Stable external components are necessary for the RC network if good timing accuracy is to be maintained. The timing resistor(s) should be of the metal film variety if timing accuracy and repeatability are important design criteria. The timer exhibits a typical initial accuracy of one percent. That is, with any one RC network, from timer to timer only one percent change is to be expected. Most of the initial timing error (i.e. deviation from the formula) is due to inaccuracies of external components. Resistors range from their rated values by .01 % to 10 and 20 percent. Capacitors may have a 5 to 10 percent deviation from rated capacity. Therefore, in a system where timing is critical an adjustable timing resistor or precision compo-

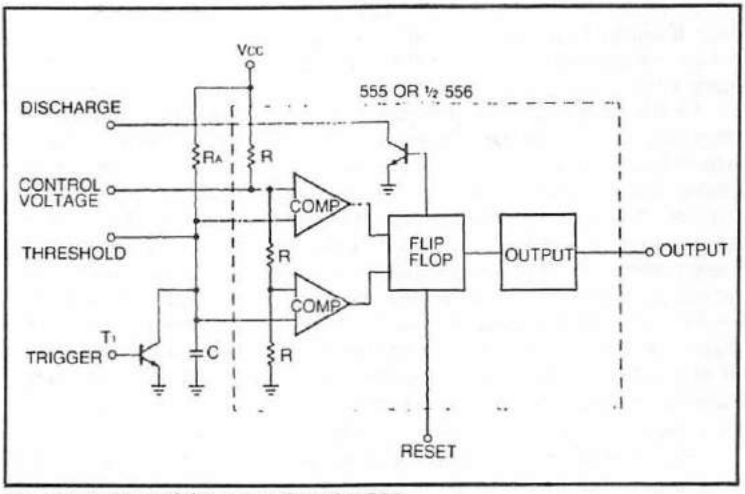


Fig. 30-11. Time-delay operation of a 555.

nents are necessary. For best results, a good quality trim pot, placed in series with the largest feasible resistance will allow for best adjustability and performance.

The timing capacitor should be a high quality, stable component with very low leakage characteristics. *Under no circumstances should ceramic disc capacitors be used in the timing network!* Ceramic disc capacitors are not sufficiently stable in capacitance to operate properly in an RC mode. Several acceptable capacitor types are: silver mica, mylar, polycarbonate, polystyrene, tantulum or similar types.

The timer typically exhibits a small negative temperature coefficient (50ppm/° C). If timer accuracy over temperature is a consideration, timing components with a small positive temperature coefficient should be chosen. This combination will tend to cancel timing drift due to temperature.

In selecting the values for the timing resistors and capacitor, several points should be considered. A minimum value of threshold current is necessary to trip the threshold comparator. This value is .25 μA. To calculate the maximum value of resistance, keep in mind that at the time the threshold current is required, the voltage potential on the threshold pin is two thirds of supply. Therefore:

$$\text{Vpotential} = \text{Vcc} - \text{Vcapacitor}$$
$$\text{Vpotential} = \text{Vcc} - \tfrac{2}{3}\,\text{Vcc} = \tfrac{1}{3}\,\text{Vcc}$$

Maximum resistance is then defined as

$$R_{max} = \frac{V_{cc} - V_{cap}}{I_{thresh}}$$

$$\text{Example:}\ V_{cc} = 15\text{V}$$
$$R_{max} = 15 - 10 = 20\text{M}\Omega$$
$$.25\,(10^{-6})$$
$$\text{Vcc} = 5\text{V}$$
$$R_{max} = \frac{5 - 3.33}{.25\,(10^{-6})}\ 6.6\text{M}\Omega$$

Note: If using a large value of timing resistor, be certain that the capacitor leakage is significantly lower than the charging current available to minimize timing error.

On the other end of the spectrum, there are certain minimum values of resistance that should be observed. The discharge transistor, Q_{14}, is current limited at 35mA to 55mA internally. Thus, at the current limiting values, Q_{14} establishes high saturation voltages. When examining the currents at Q_{14}, remember that the transistor, when turned on will be carrying two current loads. The first being the constant current through timing resistor, R_A. The second will be the varying discharge current from the timing capacitor. To provide best operation the current contributed by the R_A path should be minimized so that the majority of discharge current can be used to reset the capacitor voltage. Hence it is recommended that a 5K ohm value be the minimum feasible value for R_A. This does not mean lower values cannot be used successfully in certain applications. Yet there are extreme cases that should be avoided if at all possible.

Capacitor size has not proven to be a legitimate design criteria. Values ranging from picofarads to greater than one thousand microfarads have been used successfully. One precaution need be utilized though. (It should be a cardinal rule that applies to the usage of all ICs.) Make certain that the package power dissipation is not exceeded. With extremely large capacitor values, a maximum duty cycle which allows some cooling time for the discharge transistor may be necessary.

The most important characteristic of the capacitor should be as low a leakage as possible. Obviously any leakage will subtract from the charge count causing the calculated time to be longer than anticipated.

Control Voltage

For most applications, the control voltage function is not used and therefore is bypassed to ground with a small capacitor for noise filtering. The control voltage function, in other applications becomes an integral part of the design. By imposing a voltage at this pin, it becomes possible to vary the threshold comparator "set" level above or below the 2/3 Vcc nominal, hereby varying the timing. In the monostable mode, the control voltage may be varied from 45 percent to 90 percent of Vcc. The 45 to 90 percent figure is not firm, but only an indication to a safe usage. Control voltage levels below and above those stated have been used successfully in some applications.

In the oscillatory (free turn) mode, the control voltage limitations are from 1.7 volts to Vcc. These values should be heeded for reliable operation. Keep in mind that in this mode the trigger level is also important. When the control voltage raises the threshold comparator level it also raises the trigger comparator level by one half that amount due to R_8 and R_9 of Figure 2. As a voltage controlled oscillator, one can expect ± 25 % around center frequency (f_o) to be virtually linear with a normal RC timing circuit. For wider linear variations around F_o it may be desirable to replace the charging resistor with a constant current source. In this manner the exponential charging characteristics of the classical configuration will be altered to linear charge time.

Reset Control

The only remaining function now is the reset. As mentioned earlier, the reset, when taken to ground, inhibits all device functioning. The output is driven low, the bistable flip-flop is reset, and the timing capacitor is discharged. In the astable (oscillatory) mode, the reset can be used to gate the oscillator. In the monostable it can be used as a timing abort to either interrupt a timing sequence or establish a standby mode (i.e.—device off during power up). It can also be used in conjunction with the trigger pin to establish a positive edge triggered circuit as opposed to the normal negative edge trigger mode. One thing to keep in mind when using the reset function is that the reset voltage (switching) point is between 0.4V and 1.0V (min/max). Therefore, if used in conjunction with the trigger, the device will be out of the reset mode prior to reaching 1 volt. At that point the trigger is in the "turn on" region, below 1/3 Vcc. This will cause the device to trigger immediately, effectively triggering on the positive going edge if a pulse is applied to pins 4 and 2 simultaneously.

Tone Burst Generator

The 556 Dual Timer makes an excellent tone burst generator. The first half is connected as a one shot and the second half as an oscillator (Fig. 30-12).

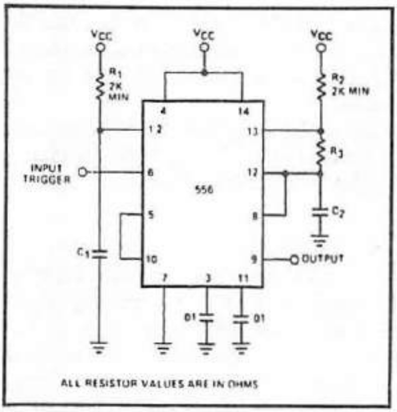


Fig. 30-12. A tone-burst generator using a 556.

The pulse established by the one shot turns on the oscillator allowing a burst to be generated.

Sequential Timing

One feature of the dual timer is that by utilizing both halves, it is possible to obtain sequential timing. By connecting the output of the first half to the input of the second half via a .001 μF coupling capacitor sequential timing may be obtained. Delay t_1 is determined by the first half and t_2 by the second half delay (Fig. 30-13).

The first half of the timer is started by momentarily connecting pin 6 to ground. When it is timed out (determined by $1.1R_1 C_1$) the second half begins. Its duration is determined by $1.1 R_2C_2$.

LONG TIME DELAYS

In the 556 timer, the timing is a function of the charging rate of the external capacitor. For long time delays, expensive capacitors with extremely low leakage are required. The practicality of the components involved limits the time between pulses to something in the neighborhood of twenty minutes.

To achieve longer time periods both halves may be connected in tandem with a "divide-by" network in between.

The first timer section operates in an oscillatory mode with a period of $1/f_o$. This signal is then applied to a "Divide-by-N" network to give an output with the period of N/f_o. This can then be used to trigger the second half of the 556. The total time is now a function of N and f_o (Fig. 30-14).

Additional 555 Notes

You have already seen what Signetics says can be done with the 555. Now we turn to a number of other sources for additional material applicable

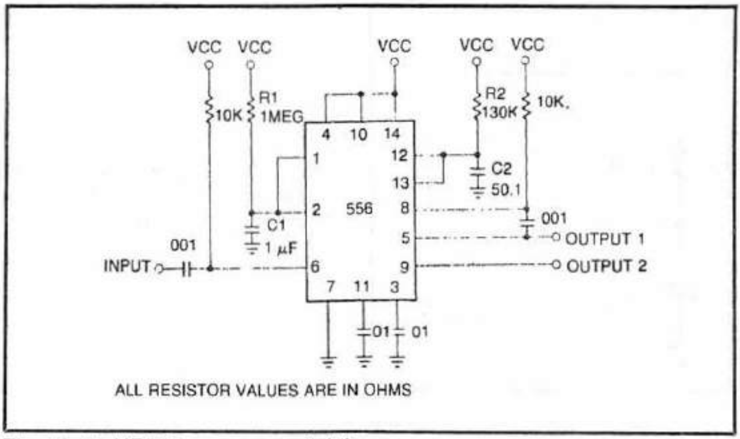


Fig. 30-13. NE556 as a sequential timer.

to Amateur repeater/remote-base systems. This material has been donated by various Amateurs. Some of it is simply observations of characteristics, while others are complete circuits.

- When triggering the 555, the trigger voltage must go to less than 1/3 of the supply voltage. If the trigger stays below that point, the output will remain "high" regardless of the timing components used. For proper operation, the triggering pin voltage must return to something above 1/3rd of the supply voltage.
- The reset pin (pin 4 of the 555) has a "no-mans-land" between 0.4 and 1 V; some devices will reset, some may not. Be sure that the logic circuit driving the reset pin does go below 0.4 V; some open-collector devices don't.
- If pin 4 is not used in a particular design, be sure to jumper it to pin 8 (V supply).
- Always bypass the control voltage pin (pin 5) with a small value (0.01 is recommended) capacitor. This pin has the capability of varying the cycle time of the 555—it can change the duration of the monostable pulse width or the astable frequency. In fact, this pin was supplied to allow the use of this device in pulse-width modula-

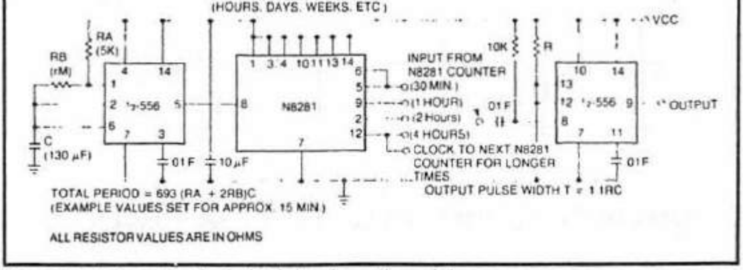


Fig. 30-14. A method of obtaining long time delays.

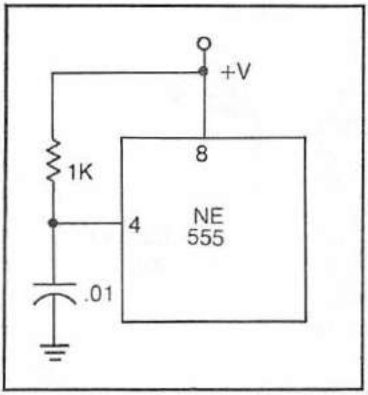


Fig. 30-15. A resistor and capacitor connected to pin 4 to avoid false triggering at power-up.

tion circuits, voltage-controlled oscillators, etc. The 555 can be RF sensitive, with pin 5 being the most critical port.

- If you are not familiar with the sensitivity of the 555 to supply voltage, certain behavioral characteristics can be almost impossible to find. In a large TTL circuit, an oscilloscope connected to the plus 5 V buss will display voltage transients which can effect the timing of a 555 timer powered by the same source. To eliminate this potential problem, the supply to the 555 must be properly bypassed. The size of the capacitor depends upon the load on pin 3 of the 555. Values can range from .05 to 50 μF or more. The capacitor should be placed close to the 555 for best results.
- Large values of timing capacitance generally go hand in hand with high leakage. High-leakage capacitors have catastrophic effects on

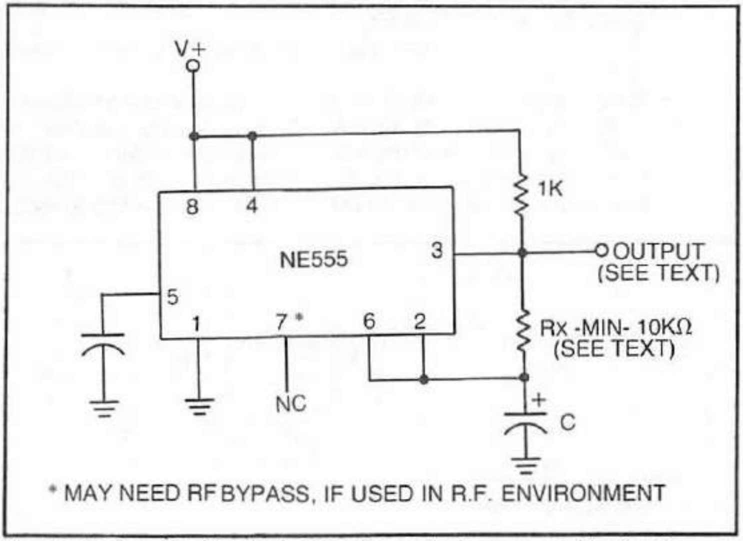


Fig. 30-16. A method to obtain 50% duty cycle from an astable circuit.

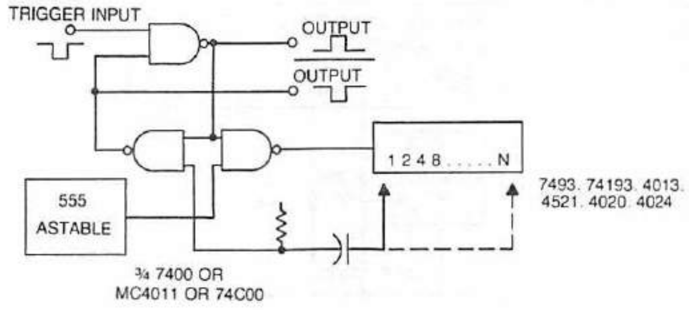


Fig. 30-17. Long time delay with both positive- and negative-going outputs.

the time delay/astable frequency. Tanalum, Polystyrene, mica, and Mylar types are recommended. Electrolytic types should be used with caution. Usually, gross timing errors can be traced to a high leakage characteristic in the timing capacitor. Never use ceramic disc types. Adjust your RC timing ratio to where any stray capacitance in the circuit will not effect the overall operation of the timer.

- When the circuit containing the 555 is first powered up, the chances are that, if the triggering can cause a problem, it will do so (Murphy's law). This can be avoided by adding a resistor and capacitor as shown in Fig. 30-15.

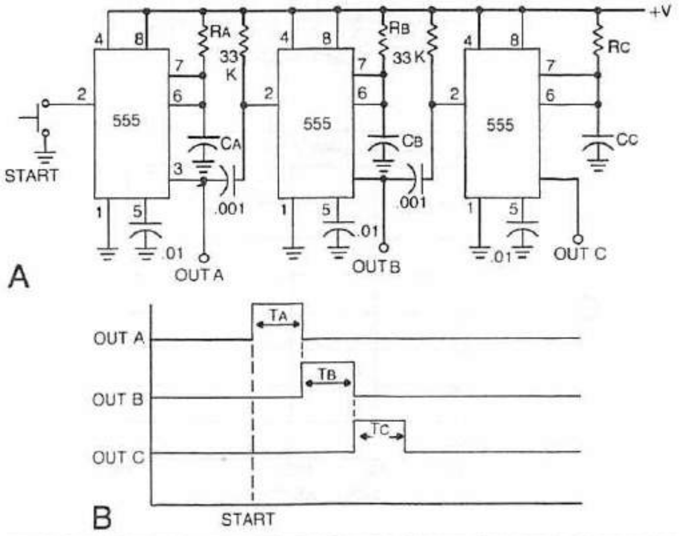


Fig. 30-18. A sequential timer, A, and waveforms, B.

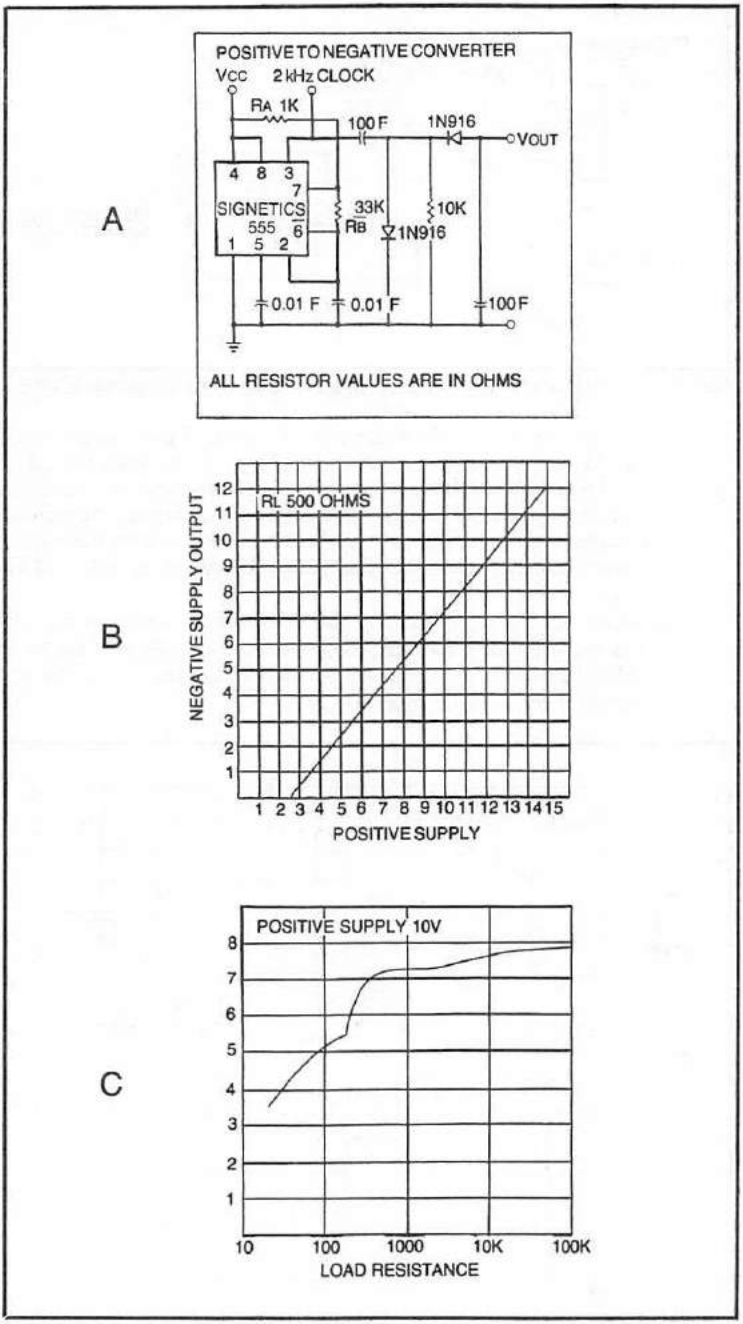


Fig. 30-19. Obtaining negative12 volts from a positive supply.

- An easy way to obtain 50 % duty cycle from an astable circuit is shown in Fig. 30-16. This circuit does have the disadvantage that it can only drive logic chips—no heavy loads. Also, there is a minor additional restriction on component value ranges. Use no timing resistor under 10k ohms. The formula for the oscillation frequency changes to:

  F = (approx) .7 / (RC)

  The output high time equals the output low time: approximately .7 (RC).
- The circuit in Fig. 30-17 is a direct replacement for a 555 in that it uses a negative-going trigger, and gives a positive-going output, with a negative-going output as an extra. The big advantage, however, is that the output can last for an incredibly long time—the pulse length is equal to the counter setting divided by the frequency (in Hz) of the astable.

With such things as the 4020, 4024, and 4521, which are 14-stage, 7-stage, and 24-stage counters, respectively, very long time delays are available, and are as accurate and repeatable as the period of the 555. The only consideration is that the trigger pulse be shorter than the output, which shouldn't be much of a problem. The 7400, 74193, and 7493 are TTL components—this circuit will work in either a TTL or CMOS configuration, but not mixed.

A single CMOS chip which can do the job of the entire circuit above, with a few extra features to boot, is the 4536 or 4541.

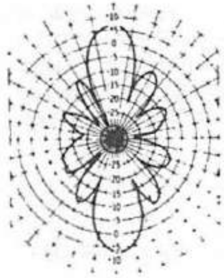
SEQUENTIAL TIMER

Figure 30-18 shows a circuit that can be used for many things that require a predetermined sequence of signals. For example, the reset-beep generator in a repeater could use a two-stage sequence; the first to delay the beep, and the second to control it's length. An example of this is shown in the porta-peter controller described elsewhere in this book.

This circuit can be extended to as many stages as you need. Each is a duplicate, except the first stage. The time duration (R & C components) for each stage can be customized.

POSITIVE TO NEGATIVE CONVERTER

Suppose you now own an operational repeater that is completely based upon a 12 VDC supply. You wish to add microprocessor control and you discover that you also need a negative voltage. A simple way to obtain that negative voltage is shown in Fig. 30-19.



Chapter 31

Hooking To The Sky

I promise you at the outset that I will not bore you to death with absolutely useless construction articles featuring antenna designs that nobody will ever build. That's the major problem with most books written on the subject of Amateur repeaters. Very few authors are willing to admit a very simple truism. Simply, there are few system owners who build their own antennas these days. Some do, I grant you, but they are in the minority. For the most part, the system owner of today either purchases a commercially made communications antenna, or antennas, cut to the exact operating frequency. Or, he modifies a particular Amateur antenna to suit his purpose. The modifications are usually in the area of strengthening the mounting for longevity in severe weather. Therefore, I will present only one antenna design—that of a "Circularly Polarized" antenna. The reason for this being that, currently, no such animal is available at a decent price.

When discussing antennas, we think of two basic characteristics: polarization and directivity. There are actually four possible antenna polarizations. Wait a minute . . . four? That can't be. There are only two: horizontal and vertical, right? Not quite—there are two other possible polarizations, but they are rarely spoken of in Amateur circles. They are "clockwise" and "counterclockwise" circular polarizations which are just now being discovered by Amateurs as a possible alternative to either vertical or horizontal polarization.

There are three basic types of directivity patterns. They are: (amateur terms)

- Omni—affords a 360 ° pattern
- Cardioid—additional directivity in one direction
- Directional—narrow beamwidth signal.

By far, the most popular antenna in today's world of Amateur relay communications is the "Omni-Directional Vertically Polarized Antenna". Such antenna's come in many sizes, and styles and with all sorts of "gain ratings". Choosing the proper antenna or antennas for your system is not as easy as it may seem. Using the proper antenna is, however, one of the most important aspects of system planning. In this chapter we hope to clear away some of the fog surrounding this mystery and thereby make your job a bit simpler.

The choice of antenna for a given installation will depend upon several factors such as system location, HAAT, type of terrain, intended coverage, and more. However, we can simplify things a bit by first gaining an understanding of how different antennas work, and from this we can make a judgement to fit our needs.

The vertical antenna is the standard in today's repeater operations. Verticals fall into two categories; unity gain and gain types. The 1/4-wave groundplane is an excellent example of a unity gain antenna. Such antennas exhibit what is termed a fairly high "angle of radiation". This means that the RF radiating from it tends to climb skyward at a fairly steep angle. Therefore, if you were to use this type of antenna atop a 5000-foot mountain, or even atop a 500-foot building, quite a bit of your system's receive and transmit capability would be aimed at the sky and not at your user. A trick used by a number of repeater operators has been to invert these antennas to lower the angle of radiation. There have been arguments both pro and con on this technique, and I do not wish to continue the argument here. Suffice to say that some improvement in performance can be obtained in this manner.

GAIN

Enter the "gain antenna." In the world of Amateur communication, most think of gain in terms of directivity. They look at their directional arrays for 20 or 15 meters and say: "That antenna has 10 dB of forward gain". This is a true statement when dealing with such directional arrays. However, when we talk in terms of vertical antennas, the term takes on a totally new meaning. Here, "gain" comes from lowering the radiation angle of the antenna to "squirt" more RF toward the ground area that can be seen from the site. We want to take the RF that now heads toward the heavens and concentrate it elsewhere. Here, then, is a good rule of thumb: If your system is in a rather high location, and your users are nearby at a much lower level, you need an antenna with a lower angle of radiation. The user, on the other hand, might want to use an antenna with a higher angle of radiation in this circumstance.

What about antenna pattern? This, again, is not all that complicated. If your users surround your site in all directions, then you need a true omnidirectional pattern to serve them. An example of this might be a system sitting in midtown Manhattan with users in all five of New York's boroughs, Long Island, and New Jersey. In such a circumstance, an antenna with a 360° pattern is necessary to service all. However, a system atop a small hill, such as the foothills to the Verdugo Mountain Chain in Los Angeles, might be shielded to the East by even taller hills. There are no users in that direction, so why bother to squirt RF into an iron-ore mountain. Here, a cardioid pattern with a major lobe into the prime service area will give better service.

Beam type antennas can also serve a useful purpose in repeater installations, such as the system being used on the WB6UBF/R 220-MHz repeater serving the area around Camino, California. Here, the system designers decided to produce a specialized-coverage pattern by using four 7-element beams and a power-divider. The results have been reported as being close to spectacular in an area noted for some rough terrain. For those not familiar with the device, a power divider is a piece of equipment that "divides up" a given amount of RF between a number of antennas. If you put 100 watts into it, 25 watts comes out of each output port. Many manufacturers can supply this item, including KLM Electronics of Morgan Hill, California.

Using beam antennas can solve several problems. For instance: When the Kings County Repeater Association placed it's WA2ZWP repeater into operation back in 1970, very little was known about tertiary operation. WA2ZWP operated "right side up" on 146.205 in and 146.805 out. It had neighbors on .22/.82 and .19/.79. These were established systems, and the adjacent-channel interference, using omnidirectional transmit and receive antennas, was unbearable. Part of the solution was found in replacing the groundplane transmit antenna with a pair of Hy-Gain 4-Element beams. In this case the majority of users were concentrated to the east, and the adjacent-channel repeaters were to the Southwest and Northwest respectively. By establishing a narrow cardioid pattern with the two 4-element beams, the adjacent channel interference to the two other systems was reduced enough to make life tolerable for all. There were plans to do the same with the receiving antenna system, however, a number of events—including my departure from New York, a new site and a frequency change—precluded this. However, even with today's more advance technology, something this simple can prove to be a real problem solver.

Another area to consider is that of coverage limitation. Here, again, the choice of the proper antenna is all important. For example: Here in Los Angeles, there are presently over 120 two-meter systems with the area-wide total close to the 300 mark. (Area-wide indicating all of Southern California plus nearby Mexico and bordering systems in Nevada. In Los Angeles proper, this is an average of approximately 2.2 systems per channel pair between both sub-bands. Many of these are low-level, or "Local" systems. It is important to keep the radiation angle as low as possible so as to keep the RF from crossing a mountain into an adjoining area where another local system might be using the same channel pair. In this situation, you strive for total saturation using a minimum amount of power, and are strongly dependent on your antenna system to make it all work. An excellent example of this is the WR6BDL system in Van Nuys. It sits in the heart of the San Fernando Valley at a very low level, yet provides excellent coverage throughout it's service area. Other than a bit of "leakage" through some of the mountain passes to the East and South, WR6BDL is the epitome of a truly well engineered "local" system. It is the antenna that makes it play so well.

You can see that the type of antenna you select for your system must be carefully thought out. Just sticking anything up may work, however, proper selection of the antenna or antennas is vital for top-notch system performance. Also, one must consider longevity. As with anything else, you get what you pay for. Therefore another important consideration is overall construction of the antenna itself. When dealing with systems installed a inaccessible remote site such as mountaintops, the foregoing cannot be overemphasized. A poorly constructed antenna will not last long on a windy mountaintop or high tower. The natural elements and seasonal changes take their toll, and antennas are no exception. Therefore, to skimp on the antenna is truly self defeating. It is for this reason that many Amateur repeater groups insist on spending the extra money to procure an antenna designed for the commercial Land-Mobile FM service, but cut to the

Amateur frequency. These antennas are quite expensive, however, the groups are willing to pay the price for the performance afforded by this investment. These antennas fall into two basic designs: "collinear" and "stacked Dipole Arrays" (also called "four-poles"). The collinear version usually looks like a long white rod with a small set of radials at the very bottom. The outer shell is normally fiberglass, and inside this housing are coaxial sections properly phased and sealed in either parafin or beeswax. The stacked dipole usually consists of four vertical dipoles spread equidistant the length of the supporting mast and either spaced around the mast for an omnidirectional pattern, or in some other arrangement to provide a cardoid effect. Both are ruggedly constructed to provide years of trouble-free service.

Though a 360 ° omni antenna in basic design, the collinear antenna can be directed into a cardioid pattern by use of either an offset kit, which place a reflector element at a precise distance from the antenna itself, or by mounting it that same distance off the side of a mast or tower. In this same way, virtually any vertically polarized antenna can be given directivity.

Two very popular antennas for both repeater operation and home station use are the Cush-Craft Ringo (with or without the "ranger" conversion) and the Hy-Gain groundplane series. While neither is designed for long-term use at remotely located sites, both have proven themselves top performers in more environmentally sane locations. I have used both in repeaters, and currently use both at my home station. I can vouch for them as meeting or exceeding published specifications. Also, a lot of top-notch systems throughout the nation sport these skyhooks.

ENTER CP

CP is short for "Circular Polarization," and in 1975, Amateur repeater enthusiasts first began to experiment with this interesting antenna design. The first to try CP was Burt Weiner, K6OQK, on his Mt Wilson 2-meter system. He used a single-bay Jampro antenna atop the KPFK transmitter tower. This was a very special Jampro antenna in that it was factory cut to 147.435 MHz—this being the receive channel for his system. The results were amazing, to say the least. Although overall signal levels were down as compared with the systems' regular Super Stationmaster vertical, the system was hearing and talking to places it never did before. Overall coverage was better and typical mobile flutter was virtually eliminated. Due to tower limitations, Burt was never able to add any more bays and, eventually, the CP was taken from the tower and the vertical reinstalled. It was obvious that more than a single bay was needed, and this was impossible to install at Burt's site.

WA6VQP was the next to experiment with CP on his WR6AJP "San Fernando Valley Local" system in 1976. Using a modification of an antenna designed by K6PUW, Jim constructed and installed a "2-bay, unity-gain" CP array which was stacked with a 3-dB groundplane. A remote switching system was installed and the users of AJP were instructed to try both antennas and, after deciding which performed better, they were to leave that antenna in service. The users were not told which was the vertical and which was the CP. Over a period of months, Jim watched with interest as user after user selected the "unity-gain" CP array over the 3-dB

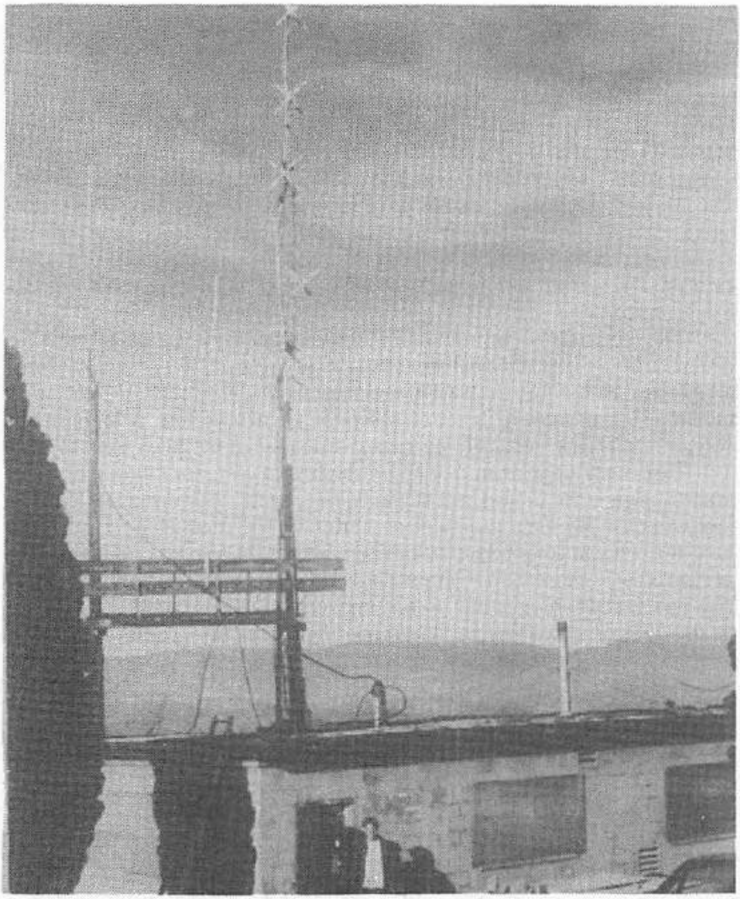


Fig. 31-1. The WA6VQP repeater/remote base on Loop Canyon Summit uses a 4-bay, 3-dB, circularly polarized antenna.

groundplane. Invariably, the user would state "less flutter" and "better overall range" as his reason. Eventually, the 3-dB vertical was taken down, since user preference had confirmed the projected technical performance. The CP did a better all around job.

Jim carried the use of CP over to his 220-MHz repeater/remote, WA6VQP/R, on Loop Canyon Summit (see Fig. 31-1). WA6VQP/R uses a "4-bay, circularly polarized" antenna. It is this antenna design that will be shown later on. Both WA6VQP/R and WA6VNV/R on Oat Mountain are proof of the superiority of "CP" over vertical polarization in mountainous terrain. Though no one has yet reported experiments with CP in cities such as New York and Chicago, where the Mountains are man-made skyscrapers and the "canyons" are the streets, it is expected that the results in those situations would be similar to what experimenters on the West Coast have noted.

CP improves all around system performance, and it helps cancel one of mobile communications worst enemies—polarization shift. If you transmit a vertically polarized signal to a receive antenna of the same polarity, with no obstructions in the way and no surfaces nearby that it can reflect from, a vertically polarized signal will reach the receiving antenna. This is the "ideal" situation, but seldom does the "ideal" exist. More often than not, the signal will reflect from some surface or another and when this happens, polarization shift takes place. You might start off with a vertical signal, but, by the time it reaches it's destination it might be any polarization conceivable. In areas where repeaters are situated on mountains with other mountains nearby this can cause some problem. However, a "CP" antenna is looking for signals of any polarization. Since, by its design it looks at any given instant in time, it always receives a signal "in phase" and could care less what the originating polarization was to begin with. The reverse holds true on the return trip. Since it transmits in all polarizations, the proper polarization component reaches the users antenna. An excellent demonstration of this is when one takes a hand-held with a "rubber duck" antenna and, while listening to a repeater transmitting CP, he turns the hand-held in a 360 ° arc: no signal change. The antenna on the hand-held can be in any plane and the signal from the repeater remains constant. This explains why much of the mobile "picket fencing" type flutter disappears on a system

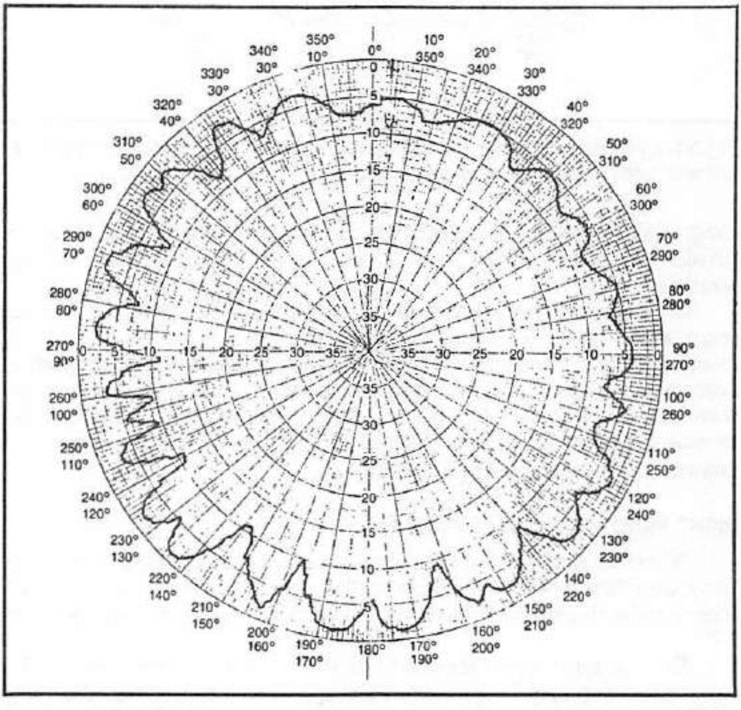


Fig. 31-2. Mobile flutter equivalent chart obtained by rotating a test antenna which was receiving a signal from a circularly polarized antenna.

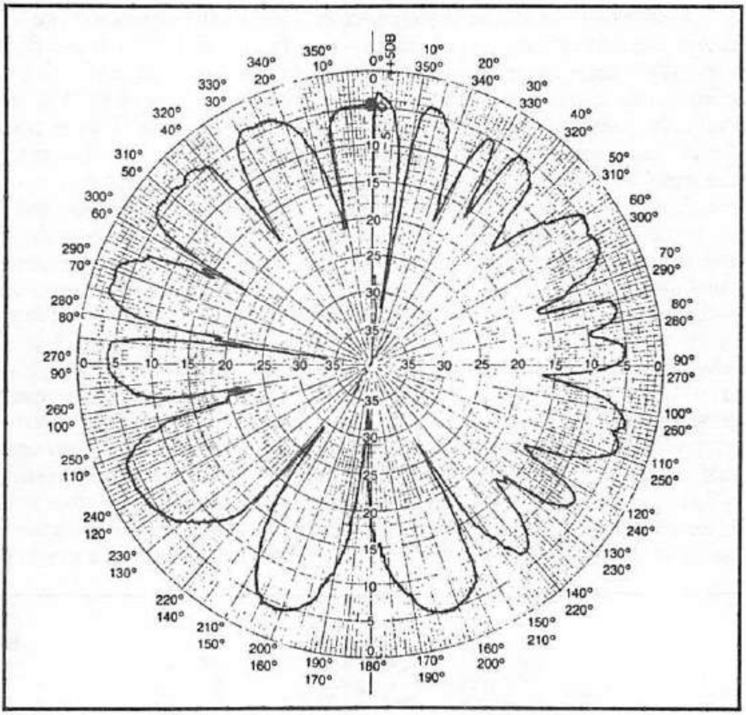


Fig. 31-3. Mobile flutter equivalent obtained in the same manner as in Fig. 31-2, but with both antennas linear polarization.

using a CP antenna. Again the analogy of the reflected signal. If you reflect a circularly polarized signal from a surface, you still retain a circularly polarized signal.

CP minimizes yet another problem encountered with pure vertical polarization: The problem ot "multipath cancellation." Let's assume for a moment that our "vertical wave" reaches the receiving antenna along with a reflected wave 180 ° out of phase with it, and is 50 % of the amplitude of the wanted vertical component. This second wave will cancel 50% of the modulation sidebands of your wanted signal, thus introducing something known as "multipath phase distortion."

RIGHT HAND VERSUS LEFT HAND CP

When we first started speaking about antenna polarization, we said there were four types: vertical, horizontal, right-hand CP and left-hand CP. Right hand is also known as clockwise CP, and left hand is counterclockwise CP.

Each designator indicates wave direction and it can be stated that the same rules of cross-polarization loss that apply to linear antennas also apply to CP. A 20-dB loss occurs between stations of opposite CP sense trying to work one another. Obviously, this indicates that some standard had to be

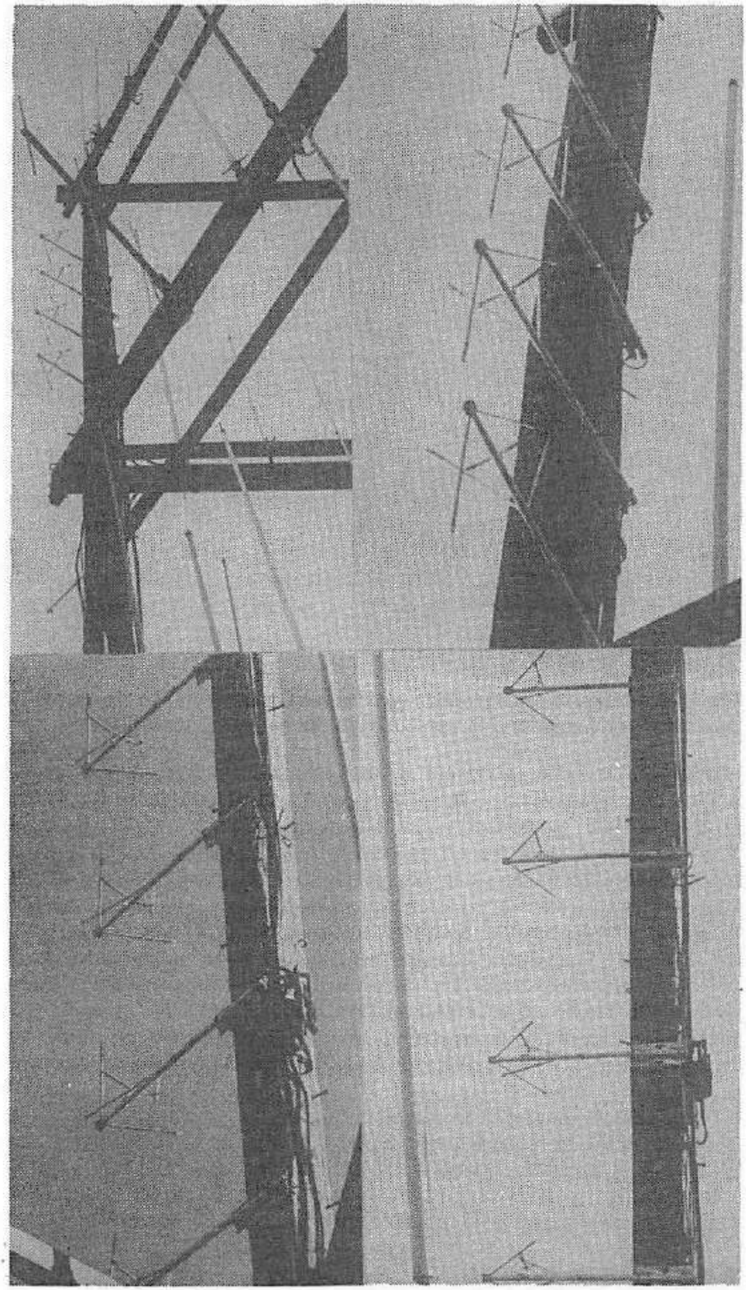


Fig. 31-4. Four views of the WA6VNV omni-directional, circularly polarized antenna system at Oat Mountain, CA (courtesy of WA6MPG and WB6LJZ).

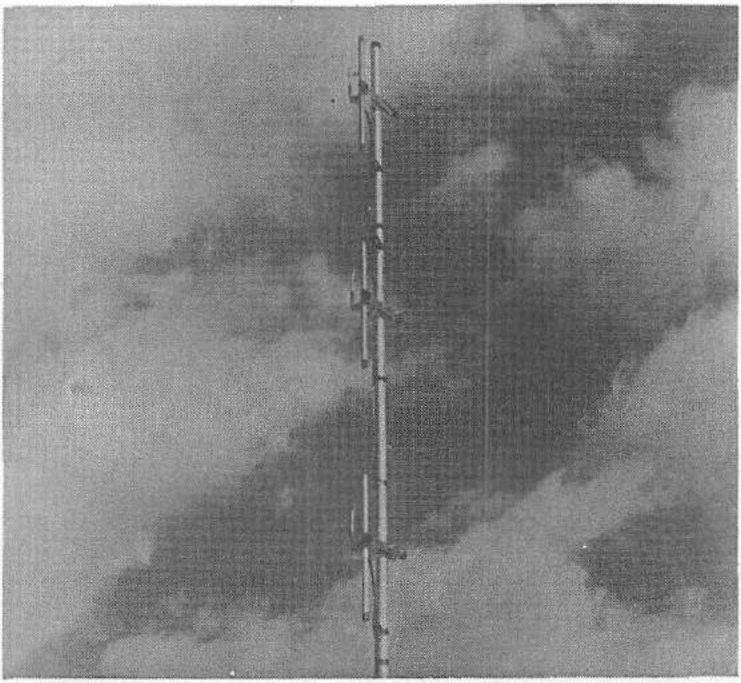


Fig. 31-5. Vertical, 4-pole antennas, such as this Cushcraft AFM series, are very popular with repeater and FM enthusiasts (courtesy of Cushcraft).

adopted for CP operation, and at least in Southern California one has. Unless directed otherwise by a coordinator and/or coordination council, "right hand" or "clockwise" CP is this area's standard.

Using CP gives the coordinator and/or council something they have never had before. It allows an on-channel 20-dB attenuation factor simply by reversing the leadwave CP of one of two systems on a given channel. This cannot be accomplished with systems using vertical linear polarization, and therefore is an added bonus when using CP antennas on repeaters.

CP has proven it has much to offer the repeater operator. Close to 85 % of the FM broadcast stations have made the switch to CP, as have a smaller number of television stations. While CP may not be the answer to every problem faced by a repeater, it has been an asset to those who have tried it.

The two computer derived test results charts, (Figs. 31-2 and 31-3,) show the fade difference between a popular 6-dB vertical antenna and the WA6VNV/R inverted crossed-dipole 4-bay CP antenna. Note the greater overall pattern stability of the CP antenna. This indicates far less flutter, though average signal level is below that of the 6-dB vertical.

A FOUR-POLE CP ANTENNA

This is the only antenna project you will find in this book. I've included it for those who wish to experiment with a CP antenna on their system. It is simple to build, requiring only a pair of Cush-Craft 4-Pole antennas, a short length of type RG-59/U 75-ohm coaxial cable, and four type PL-259 connectors. That's the entire parts package.

Step one is to assemble one of the two 4 Pole antennas according to the directions supplied. Do not attach the phasing harness yet; this will be done later. Next, tilt each dipole 45 ° from its vertical axis, either left or right. Be sure that the portion of the dipole with the gamma match is facing skyward. Store the phasing harness from the second 4-pole it will not be needed. It is wise to keep it as a backup. Mount the other four dipole elements, again with gamma match pointing skyward 45 ° from the vertical axis in the opposite direction, and directly in back of, the first set of elements. When finished, you should have an array exactly like the one in Fig. 31-4.

Next, prepare four ¼ wave lengths of 75-ohm coax. Remember to calculate for your receiver frequency, and include the velocity factor multiplier for the type of cable used. Looking at the antenna from the front, assume that all right-hand elements will be direct fed from the Cush-Craft supplied matching harness. Connect them per Cush-Craft's instructions.

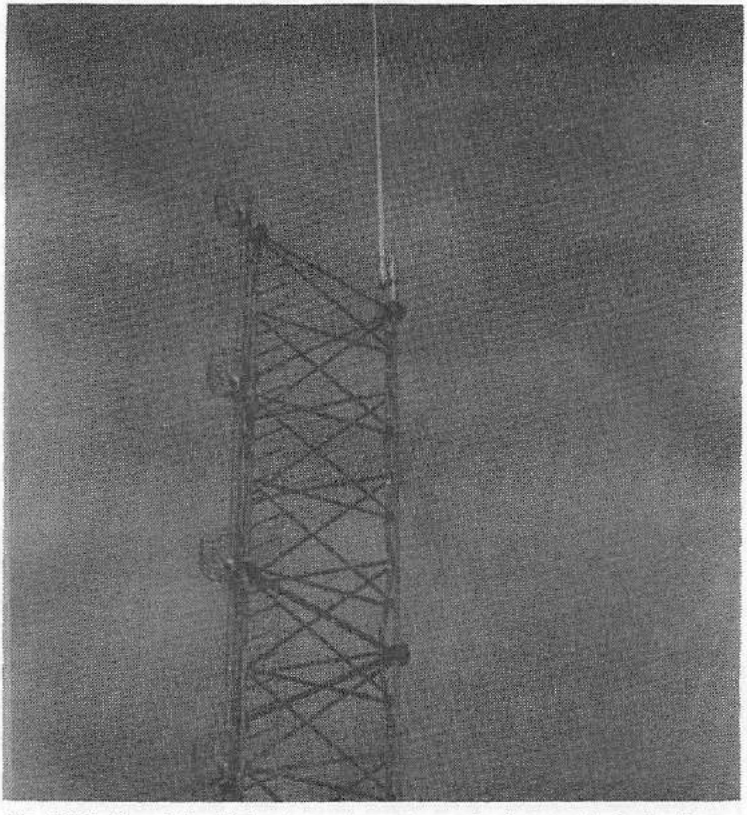


Fig. 31-6. One of the highest repeater antennas in the country is the Super Stationmaster of WR6ABE, atop Mt. Wilson at nearly 6000 feet above sea level.

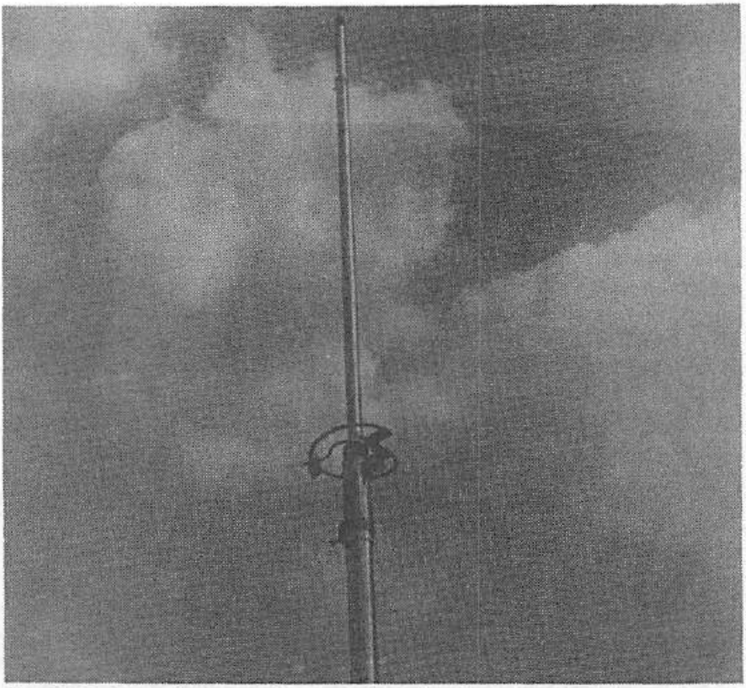


Fig. 31-7. A popular, rugged, easy-to-install antenna for repeaters or home stations—the Ringo series (courtesy of Cushcraft).

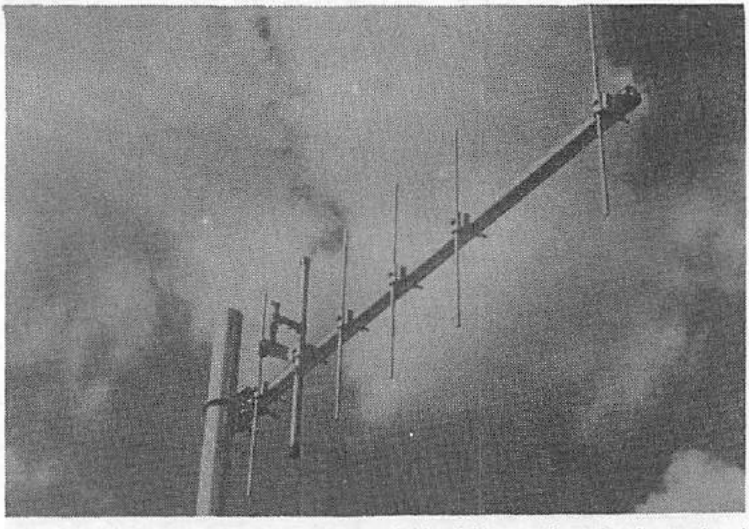


Fig. 31-8. Directional antennas are essential for linking, and can be directed and phased to provide unique patterns for your repeater coverage (courtesy of Cushcraft).

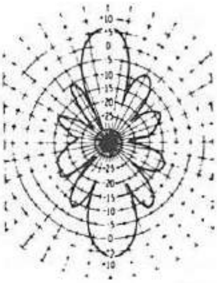
Solder a PL-259 Plug to one end of each of the four ¼-wave matching sections, and insert same into each left hand element, and solder each of the free ends of the matching sections to the respective "hot" and "ground" terminals on the right-hand element.

Tuneup is a bit more complex than for the normal 4-pole. However, what you want to do is basically tune each set of elements for minimum VSWR, as a pair. It should be noted that some slight mismatch does exist, however, there is sufficient range in the gamma-match devices to tune out the introduced reactance. Also, there will be some interaction between the element pairs when tuning, so keep this in mind. Basically follow the outlined tune-up procedure supplied by the manufacturer, duplicating each step for the extra dipole element.

The next step is important. It will be assumed that you know where your system previously had dead spots. Drive through them and note any difference. Also note that the overall signal may be down a few db from pure vertical polarization, but also pay close attention to fading and flutter. Both should be remarkedbly reduced, and overall coverage should be improved.

Other antennas are shown in Figs.31-5 through 31-7. A directional antenna is shown in Fig. 31-8.

Chapter 32
Antenna and Tower Safety



When we speak about antennas we usually think of radiation patterns and such. There is another important thought about antennas, and that is safety. The antenna is exposed to mother nature, and at times she has been known as a rather cruel lady. A good lightning strike can easily wipe out an entire system, along with anyone who happens to be in the vicinity at the time. Strong winds have been known to topple towers, and bend vertical antennas in shapes resembling pretzels. There is no way to completely avoid disaster, however some careful forethought can go a long way in minimizing the effects of nature's onslaughts.

We must also consider the human factor. Humans are not infallible, and do make mistakes aplenty. Many times we get away with it; Sometimes we don't. We tend to do things in too much of a hurry, and the end result can be disaster. Let's look at some of the things that can be done to make sure that the antennas we install at our site will remain there.

MOUNT SELECTION

Do not choose a mounting spot for your antenna simply because it is convenient. Your most important consideration should be of long-term durability. You already know the physical characteristics of your antenna system, including height, weight, and wind-loading factor. This information must be used to guide your selection of the mounting structure. There is no sense in putting an antenna with a 100 MPH wind-loading factor on a mounting structure that bends in a 20 mph wind!

There are a great number of antenna mounting possibilities, but those most popular are towers, telescopic masts and, in the East, concrete structures such as building walls and the like. It is important to ascertain the ability of the structure to support your antenna, prior to the installation itself. Here, good judgement and some knowledge of structural integrity is a must. If you do not possess this ability, locate someone in your group who does, or, if necessary, call in a professional and pay his fee. It can be worth the expense in the long run.

MOUNTING HARDWARE

This is a general category that covers everything from brackets to nuts and bolts. It is important to obtain mounting hardware that is rugged. What may suffice at a home installation may twist and turn on a hilltop or tall building. It is important to stay clear of soft metals such as copper and brass. True, neither will rust, however they do not have the necessary strength to properly support a large antenna. Stainless steel is the best, but the most expensive. However, as many system owners have learned, this expense is minor when compared with the cost of total antenna replacement. Do not skimp on hardware. It's far better to over do it than to get a call from the site owner to tell you that your 4-pole is horizontal on the ground, or interleaved with three other antennas from other services.

LIGHTNING PROTECTION

Tall antennas and support structures are natural lightning rods. A lightning strike to a system without lightning protection can be devastating. Even a nearby strike has been known to cause failure of solid-state devices. You can never protect your system "too much" against the possibility of a lightning strike. You should procure any books on this subject that can be garnered from the local library, or elsewhere, and read them thoroughly. If nothing else, be sure that the antenna, and any support structure such as a push-up mast or tower, are properly grounded to a low-impedance earth ground. The same holds true for the system and rack cabinet itself. This will not afford total lightning protection, but is the first step in that direction.

CLIMBING TOWERS

Never, under any circumstances, climb a tower in high winds or during an electrical storm. Even in good weather, be sure you are wearing an approved safety belt and that you have a safety man along, watching every move you make from the ground. If you have never attempted climbing a tower before, either find an instructor to teach you the proper safety climbing techniques, or hire a professional to install your antenna system for you. Spending years in a hospital bed or winding up in a pine box is not worth the minute savings to be had by trying to do a job you are not prepared to do safely. Even a professional installer will tell you that tower work is extremely dangerous. Heed his words—he knows.

THE ANTENNA ITSELF

Choose an antenna the way you would a home. After all, you hope that, once it has been installed, it will provide many years of trouble-free operation. Pay as much attention to structural specifications as you do technical specifications. If an antenna has 90 jillion dB of gain, but can only survive a 2 MPH wind load, then it's not worth beans on a hilltop, tower, or tall building. Until recently, the only recourse that Amateurs had in purchasing truly sound antennas for repeater service was to deal with a commercial land-mobile antenna manufacturer, and pay his price for an antenna cut to the Amateur frequencies. However, in the past few years, many Amateur antenna manufacturers, recognizing the need for repeater and remote-base antennas capable of long-term durability in remote locations, have come forth with some truly great designs. In many cases, these antennas can be purchased off the shelf, and then field adjusted to the exact operating frequency. However, one suggestion, for what it's worth. Look carefully at the advertisement to be sure that the antenna is designed for repeater use. If the manufacturer makes that claim, he usually is willing to back it up.

GUYING AN ANTENNA

There will be cases in which a particular installation will need guy wires on the support structure. This is especially true when using push-up masts and light-duty towers. If you must guy your support structure, use only high-quality, stainless-steel guy wire, and high-strength egg type insulators rated for at least twice the expected wind loading factor. Whenever possible, guy the structure in four directions, 90° apart, with all guys equi-distant from the center of the support structure. Figure one set of guy wires for each 10 feet of support structure or fraction thereof. Use separate guy hooks for each set of guy wires, and if mounting on a rooftop, do not depend on the type of guy hook that simply screws into a ceiling beam. In these cases, drill through the roof and beam, and use guy hooks that go through this hole. Install a thrust plate between the nut, lockwasher, and the beam itself as shown in Fig. 32-1. This takes the load off the guy hook and places it on the building structure.

While we're on this subject, always be sure that a roof can properly support a tower or mast. If the roof is old and worn, if the beam structure of the building is decayed or rotted, then do not mount the tower on the roof unless you want it to come crashing into the radio room. Carefully inspect the roof support structure, or have it professionally inspected and certified safe, prior to beginning your installation. Better safe than sorry.

Turnbuckles should be used at each guy hook, placed about 9 inches up the guy wire from the hook. Turnbuckles make tension adjustments of the guy line quite easy. In that regard, always adjust guy lines for equal tension, so that no guy line is doing more than its share of support.

If you have any doubt whatsoever as to what type of guying is necessary for your particular installation, do not hesitate to contact the manufacturer of the tower or push-up, and tell him the type of antenna, its wind-load factor, the type of site, average weather conditions, the way the structure is mounted, and all aspects of the proposed installation. Let him guide you to a successful and safe installation. He knows his product and its safety limitations.

Unless you plan a low-level installation of less than 10 feet above the roof line, do not use conventional television-antenna mounting and guying materials. This hardware was meant to support lightweight television receiving antennas at low heights and under homeowner conditions. It was not meant to support a "tower" or "big stick antenna." Purchase commercial-quality hardware and guying materials from a distributor specializing in such products. If he has a number of grades of materials available, insist on the very best.

MAINTENANCE OF ANTENNA SYSTEMS

Just as you will perform routine maintenance on your RF hardware, the same goes for your antenna system. On a regulator basis, you should inspect the support structure, guy wires, transmission line, connectors, and every nut and bolt. Replace, as soon as possible, any rusted guy lines, cracked insulators, corroded nuts and bolts, corroded or rusted hardware, etc. Do not do this by yourself—especially where climbing a tower is involved. In the case of towers, it is recommended that they be painted annually with a protective tower paint to ensure longevity. Also, if yours is a

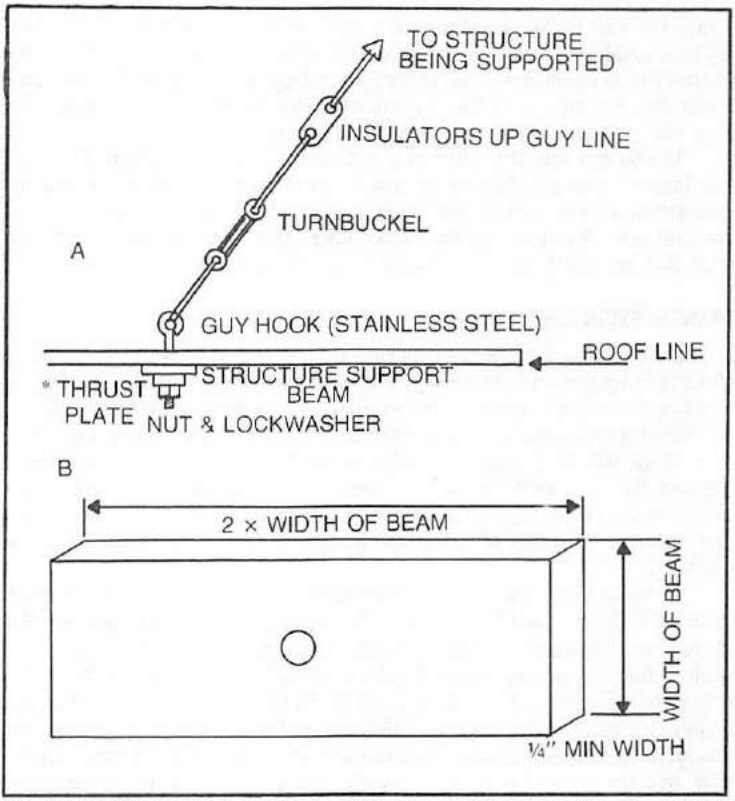


Fig. 32-1. A thrust plate should be used when a guy-wire is attached to a roof. It is simply a metal plate with a hole, B.

lighted tower, be sure that all tower lamps light to ensure its visibility to air traffic. In most cases, lighted towers are usually the property of another, with space either rented by or donated to the Amateur group using the structure. However, there are some Amateur groups who own such structures, and are totally responsible for their day-to-day maintenance. Even if the service responsibility for a lighted tower is not yours, if you notice that one of the lights is out, it will not hurt to report this fact to the person responsible for the structure.

Antennas can be protected by annually or semi-annually spray painting them with a protective acrylic. I have used *Krylon* brand Clear Acrylic Spray for many years, with excellent results. Beware that this and similar sprays are nonconductive and should never be applied until an antenna is completely assembled and all cables and transmission lines are connected, secured, and waterproofed.

Which brings us to waterproofing connectors. There is no way to be sure that moisture will not enter a connector. However, the better the job you do of waterproofing them, the less will be your troubles. A simple, effective way to assure a watertight connection is to coat the completed connector with RTV, or a similar silicone compound, and then permit it to dry thoroughly. Next, wrap a minimum of six layers of plastic electrical tape around the connector or connectors, overlapping seams each time, and continuing the tape onto the transmission line itself for about six inches. This will give you a fairly watertight connector.

As you can see, the antenna is not just something you hang in the air and forget. You should pay as much attention to the antenna and its installation as you would any other aspect of system construction and maintenance. A smart system owner takes this into account, and never finds that his hilltop antenna is now located elsewhere.

TRANSMISSION LINES

There is much to be said on this subject and we could easily spend hundreds of pages on it. However, there are a few basic rules one can follow to guide them toward proper transmission-line selection. We start with a blanket statement that says avoid RG-58 U cable for runs longer than a few feet. While RG-58 U might be sufficient for short interconnects, at VHF it exhibits far too much loss when used in the lengths usually necessary between the system and its antenna. It's ridiculous to interconnect a 9 dB gain antenna with a 0.2 μV receiver, and place 6 or 12 dB of loss between the two.

As an absolute minimum, use type RG-8 Polyfoam cable for runs in excess of 10 feet, and be sure that this is a high-grade cable and not the cheapie stuff designed for CB operation. The problem with the inexpensive cable is that it is poorly shielded and has a tendency to contaminate after a few years of exposure to the elements. Before purchasing RG-8 cable, inspect it's quality. Cut open a small portion of it, and note the outer jacket material, the completeness of the braided shield, the type of inner insulation, and the type of wire in the center conductor. Ask the salesman to check if the outer jacket is "anti-contaminating" in nature. If he says no, avoid the cable. Note carefully the braided shielding. Can you see the inner insulation through it? If you can, then the shielding is insufficient. Be sure that the inner insulation is "low-loss foam," and that the center conductor itself is stranded copper and not some alloy material. If the cable meets this criteria, it probably will be good for runs up to 100 feet.

When you exceed the 100 foot line run, it is best to use something called "hardline." This type of cable is more expensive than normal coax, however, it is to be considered a "must" if you are seeking peak system performance. Hardline is marketed by various cable manufacturers under various trade names, however, it basically is a solid-outer-shield coaxial cable that comes in various thicknesses from about ½ inch up to several inches in diameter. Another rule of thumb is that the larger the cable diameter, the lower the loss per foot. If you really want to be exotic and go for broke, several cables are available which are designed to be pressurized with an inert gas to lower losses and prevent contamination. However, except for the very rich, such cable as this is out of the average amateur's price range.

One word of caution in regard to hardline cables. Never use unjacketed cable. After a short time, exposed to the elements, corrosion points can develop between the cable and other metallic surfaces it may contact, thereby creating unwanted noise. This can also become a source of IMD mixes. Many site owners these days forbid the use of unjacketed transmission line, and it is wise to check if any such restriction exists at your site before you use any unjacketed cables.

As with everything else, our advice is "don't skimp." For a system installation to be successful, a definite financial investment is required. It is unwise to skimp in any aspect of system implementation and, in the case of transmission lines, it is a foolhardy move indeed.

TRANSMISSION LINE AND CONNECTOR GUIDE

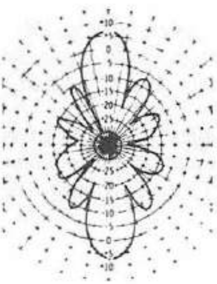
Transmission Lines

PREFERRED TYPES (50-ohm Z)
RG-213
RG-214
RG-223
RG-316
RG-188
Hardline (semi rigid, foam filled)

Connectors

PREFERRED TYPES
Type N
Type HN
SMA
TNC

Due to impedance mismatch at higher frequencies, weather sealing characteristics, RF arcing, RF noise, and mechanical instability in long-term use, avoid using PL-259, SO-239, BNC, "Phono," and any bayonet type connectors in repeater service. Many IMD and noise problems are due to poor RF connections in or near strong RF fields.



Chapter 33

The Remote Base

Earlier in this book we briefly encountered another side of Amateur technology: The Advanced Format Relay Device. Included in this group are systems such a Remote-Base operations, Simplex Autopatch systems, In-Band Linear Transl tors, and Amateur Fast-Scan TV Repeaters. This section will begin with a look at the Amateur remotely controlled base-station. We are very lucky to have obtained the permission of *ham radio magazine* to reprint from their April, 1977 issue an article titled: "The Remote Base:: An Alternative to Repeaters." This article was written by two of California's most knowledgeable FM enthuiasts, Gordon Schlessinger, WA6LBV, and William Kelsey, WA6FVC. I could spend many hours and pages extolling the credibility of these two gentlemen; of their accomplishments and the service they have provided to the Amateur community. However, I think what you are about to read speaks for itself.

With sincere thanks to Mr. T.H. Tenney Jr, we present the following, copyright 1977 by Communications Technology, Inc. Greenville, New Hampshire.

THE REMOTE-BASE CONCEPT

While both remote bases and vhf fm repeaters operate from elevated locations, it should be clearly understood that a remote base is *not* a repeater station. Major differences exist between them in construction, operation, and licensing; these differences are discussed later in greater detail. Most important, however, is the difference in intent of the two stations. Repeaters exist primarily to extend the intracommunity range of user mobile and hand-held portable stations, most operators of which are *not* owners or control operators of the repeater. Remote bases, on the other hand, are extensions of the personal stations of their owners and are operated generally only by control operators.

Figure 33-1 presents the evolution of the remote base concept. A typical amateur station is depicted in Fig. 33-1A, for the sake of discussion let's assume that it's an fm base station. The owner/control operator talks on the local microphone, listens on the local speaker, and manually turns the transmitter on and off. All controls are at arm's length. This has been the typical style of amateur operation on all bands since the inception of ham radio.

Let's now assume, for reasons of space limitations, that it is inconvenient for the amateur to keep his fm base equipment at his operating

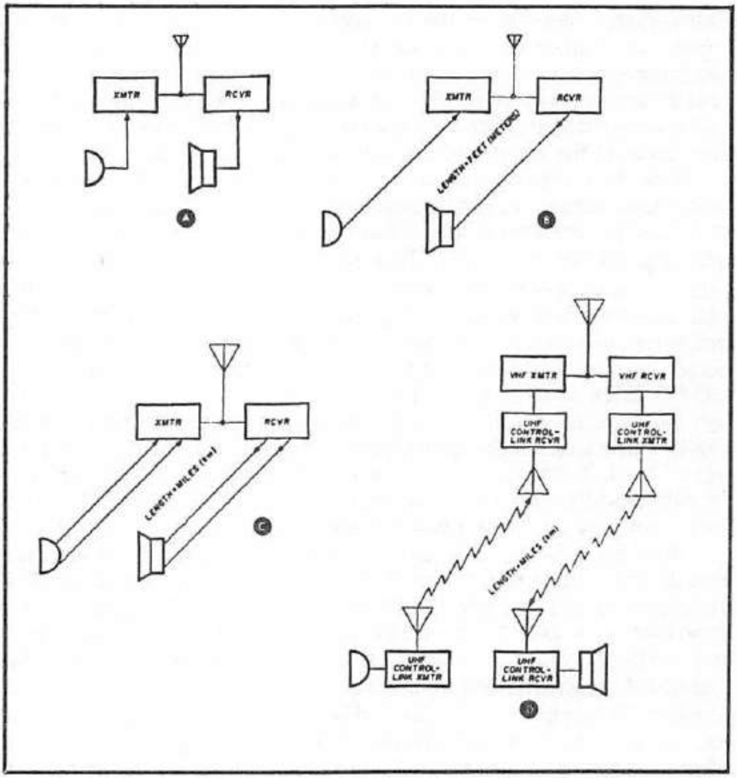


Fig. 33-1. Evolution of a remote-base station. A typical locally controlled station is shown at A. Extended local control at B has microphone and speaker on same premises but some distance from the equipment. A wire-line controlled remote base is shown at C, where the separation is extended by telephone lines. At D, the wirelines have been replaced by radio links, otherwise it is the same as in C.

position. Since fm stations are operated on crystal-controlled, fixed-tuned channels, it's not necessary to have direct physical access to the transmitter and receiver for tuning purposes. Therefore the amateur may elect to place his base equipment in his basement, attic, or garage, and extend the microphone, speaker, and push-to-talk lines back into his operating position (Fig. 33-1B). Many commercial fm base stations include provisions for doing just this. The amateur is now operating his base station remotely by wire line, although for licensing purposes the station is still under direct control as long as it is entirely contained within the amateur's fixed station license location.

In Fig. 33-1C, we extend the operating range of the fm base station by relocating it to a higher elevation. It might be situated at a friend's house on a hill, on a mountain top commercial two-way radio site, or on top of a tall building—all depending on the local geography. The station is still controlled and operated by wire line, but in this case the length of the control line is measured in miles (km) rather than in feet (m). (The technical details of the control system depend on the characteristics of the wire-line pair, its length, and whether or not it is leased from the telephone company). This installation is now a remotely-controlled base station, or remote base, and it must be licensed as a remotely-controlled station. Few, if any, southern California remote bases are wire-line controlled, but the idea has merit for other areas of the country where distances and topography permit.

Now, let's assume that no wire lines can be run to the proposed remote base-station location because of expense, distance, or inaccessibility. It then becomes necessary to control and operate the remote base by radio (Fig. 33-1D). FCC rules, (Part 97.109a), require that radio remote-control ed links operate on frequencies above 220 MHz. While some remote bases operate with 220-MHz radio links and a few others use the amateur microwave bands, the vast majority of remote base operators have elected to control and operate their stations through radio links on the 420-450 MHz amateur band. The reason for this is the availability of high-quality, surplus, commercial fm equipment designed to operate in the 450-470 MHz land mobile service band, or the 406-420 MHz government service band. The former set of radios can be easily retuned to operate in the 440-450-MHz segment of the amateur ¾-meter band, while the latter set converts easily to the 420-430-MHz segment.

Note from Fig. 33-1D that the control link must be bidirectional. Speech and control information is sent from the local uhf control-link transmitter to the remote base uhf control-link receiver. The information is demodulated and used to operate the vhf fm transmitter. Signals received by the remote base vhf receiver are used to modulate the remote uhf control-link transmitter and are then recovered by the local control-link uhf receiver. The entire control link could be operated on a single uhf channel but this is technically cumbersome. It has become customary to use separate channels for the uhf uplink and downlink. Spacing between the two control-link channels is typically on the order of 5 MHz, a separation sufficient to allow *all* uhf receivers to function properly while their associated transmitters are operating. Thus full two-way duplex operation of the control link is permitted; the control operator can simultaneously transmit signals to, and receive signals from, the remote-base station.

The locally-controlled fm base station in Fig. 33-1A has now grown to become the radio-controlled remote base station in Fig. 33-1D. Fundamentally, however, the only significant change between the two stations has been the replacement of three pairs of wires by one pair of 450-MHz radio links: the pair connecting the microphone to the transmitter, the pair between the receiver and its speaker, and the push-to-talk line pair.

REMOTE-BASE ADVANTAGES

To this point we've discussed the concept of the radio-controlled remote-base station operating on fm simplex channels. While many southern California remote bases have been established to do just this, the description above is actually a restricted view of the capabilities of remote bases. In point of fact, the existence of the basic radio link and control equipment, together with the physical location of the remotely controlled station, represent a resource that can be developed: radios of any type of emission on any amateur band, from 1800 kHz to 10 GHz or higher can be operated remotely. The remote base, for example, allows operation of high-power transmitters, such as on the 50-MHz band, in areas where TVI is a problem. It allows operation on any amateur band where antennas can't be erected at the control operator's location. It affords improved operation on the hf bands where space for efficient antenna systems may be more easily available at the remote-base site.

A remote base offers the opportunity for a group of amateurs to relocate all their radios at one central point while achieving antenna space advantages on hf and height advantages on vhf/uhf. This relocation includes not only home-station radios but mobiles as well. All may be replaced with one uhf radio per location, thereby saving on duplication of radios among several home station and mobile installations.

Those remote-base stations that operate on the fm simplex channels promote spectrum conservation in several ways. With their extended local operating range, they provide interference-free regional-area communications. This can relieve congestion on the hf phone bands by shifting local-area communications to vhf. Because remote bases operate as simplex stations, each occupies only one vhf channel at a time (i.e., 146.940 MHz) rather than two required by a repeater (i.e., 146.340 and 146.940 MHz). Additionally, by the nature of the remote-base design, a control operator always monitors the channel of operation with a mountaintop receiver before transmitting. Thus activity on the operating channel over the entire remote base transmitting range can be easily detected and inadvertent interference avoided. The same is true for repeaters only when a separate receiver and auxiliary link system is used to monitor the output frequency from the repeater site.

Finally, a remote base usually represents the desire of a group of active vhf/uhf amateurs to build a communications system. In deciding to build a remote base, the constructing group does not require the use of the limited set of 2-meter repeater channels. This translates to spectrum conservation. In the southern California area it would be impossible to fit more than the one-hundred remote-base groups into individual 2-meter repeater pairs, even when using 15-kHz channel spacing and all the simplex channels. While it's true that each remote base requires a pair of dedicated channels, these channels are in the spacious 440-450 MHz region. On a narrow-band deviation (±5 kHz) basis, this region of the spectrum contains a potential 200 pairs of channels, with another 200 pairs in reserve between 420 and 430 MHz.

CONSTRUCTING A REMOTE BASE

Occasionally an individual will undertake the entire job of designing, building, and installing a remote base. He will then either operate it as his own station, or may invite his friends to use the remote base as co-control operators. More often, in southern California, at least, a group of individuals will be formed to build and operate the remote base, thereby sharing the financial and technical responsibilities. The following comments, although addressed primarily to the group-ownership case, apply as well to single-owner bases.

Administrative and Technical Responsibility

A remote base is a communications system that contains separate but intercommunicating radios. The cost and effort to build and operate a remote base is greater than that required to operate a home station, so careful attention should be given to financial and technical responsibilities. One member of the group should be responsible for handling and reporting finances. Provisions should be made for one owner selling his equity in the remote base in the event he must move out of the area. Provisions also should be made for including new members or owners. Lack of adequate preparation in this area has been an historical source of conflict in many remote base groups.

One individual should be responsible for obtaining the site for the remote base, which should be the first task undertaken and completed. When the site involves rental of space at a commercial two-way radio installation, it has been found best to have a single individual from the group maintain relations with the site owner. One individual will have to arrange for licensing the remote base, whether it is in his name or in that of a club station. Additional non-technical duties that may need to be delegated include a) obtaining supplementary permits (for example, from the Forest Service, Bureau of Land Management, local government authority) to operate the station, b) maintaining memberships in regional amateur radio associations, and c) providing for fulfillment of public-service commitments.

Technical responsibilities in establishing a remote base should be divided into design, construction, and installation and maintenance areas. A single individual should have overall responsibility for the design of the entire system, although he may wish to delegate specific design projects to others. Particular attention should be given to interfacing between the various subsystems, such as audio and control signal levels between rf hardware and the control system.

Once original equipment designs are complete, construction of individual components can be delegated to group members. Emphasis should be placed on building for reliability, both in selection of components and in construction practices. One or two individuals should assume the responsibility of tuning the rf hardware, integrating the amateur-constructed subsystems into the final assembly, and performing on-the-ground checkout.

Maintenance. When installation of the remote base is completed, the maintenance team assumes responsibility for continued operation. These people should be equipped with the specialized test equipment (wattmeters, signal generators, frequency and deviation meters) for servicing fm communications systems. Inevitably there will be an initial period of system debugging as various design and subsystem deficiencies become apparent. Frequent trips to repair and service the remote will later taper off to occasional visits for scheduled maintenance. At this point the design team will probably begin work on improved subsystems to be retrofitted into the existing remote base, or perhaps better quality rf hardware will be acquired and put into service. Few remote bases are ever truly "completed."

Rf Hardware

The remote base typically will consist of commercially manufactured rf hardware and amateur-built control systems. Antennas may be either commercially manufactured or home built. In the selection of transmitter and receiver strips, southern California remote-base groups invariably use late-model commercial equipment. All or partially solid-state equipment is preferred for greater reliability, although high-quality all-tube equipment has performed well at some installations for many years. Receivers should have good sensitivity (fet preamps may be added) as well as excellent rf selectivity and cross-modulation rejection; many busy commercial radio sites contain very heavy rf fields. Vhf receivers and transmitters should be capable of operation on several different channels, so that the remote base may be switched to operate on whatever channel the control operator wishes to use. The vhf transmitters should be capable of moderate power output (30-100 watts), and should be free from spurious output. A remote base operating from an elevated location with a few hundred milliwatts of spurious output will certainly make its presence known.

Commercially manufactured resonant cavities are often used ahead of the entire vhf portion of the remote base to provide additional rf selectivity. The uhf remote base control-link radio should be the best that can be purchased, since it will be limiting factor in using remote base from distant locations. Matching commercially manufactured 110-Vac power supplies for fm installations are preferred to home-built supplies since they provide the exact voltages required, have provisions for properly interconnecting the transmitter and receiver to other equipment, and are usually rated for continuous-duty operation under severe environmental conditions.

Antennas

Antennas and transmission lines for the remote base should be selected with regard to survival under severe weather conditions. Antenna gain, easily obtainable at vhf and uhf is an additional factor to be considered. Remember, however, that many "gain" antennae have major radiation lobes directed at the horizon; for a mountaintop installation it may be preferable to select antennas that radiate their major lobes below the horizon. Transmission lines should exhibit the lowest loss possible; weak received signals and expensively generated vhf and uhf power can be lost in inferior coax. If available, commercially manufactured Foamflex should be used.

Control Systems

Control systems are the heart of a remote base; they are always amateur constructed. In southern California they vary in complexity from simple audio-tone decoders that drive rotary stepping switches to sophisticated multilevel digital logic circuitry. These advanced systems allow any piece of rf hardware in the remote base to be inconnected with one or more of the remaining pieces in various combinations. Control systems reflect individual needs and capabilities; space prohibits giving specific examples.

A control system performs several functions in addition to enabling transmitters to be turned on and off. In general, the control system must provide for:

- Authentication and decoding of the received control signals.
- Selection and activation of the required transmitters and receivers.
- Selection of specific frequencies to be used within each transmitter and receiver.
- Processing and conditioning of audio

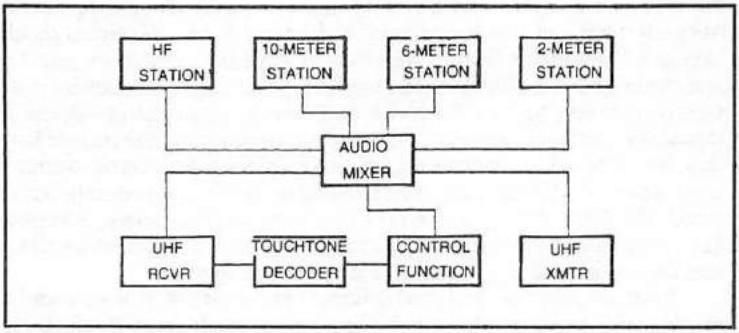


Fig. 33-2. A block diagram of a typical remote-base station. Control signals are decoded, processed, and used to select the type and band of operation. Speech is routed to the selected station through the audio mixer.

- Automatic indentification of active transmitters.
- Automatic timing of transmission length to provide ultimate shutdown protection should the control link fail.

Typically, remote bases are controlled by specific audio tones sent along with speech on the uhf uplink channel. The use of *Touch-Tone** audio encoders for this purpose has become relatively standard. The control link usually also contains a subaudible continuous tone squelch signal (*Private Line, Channel Guard*, etc.) as a verification device. Audio-tone decoders, logic circuits, and audio processors are matters of personal preference and design, although some circuits have been published. Timers and IDers are well documented in amateur literature.

Packaging

It is considered good construction practice to build all control circuits, timers, audio processors, and identifiers on standard-size edge-connector cards for insertion into a card rack. Interconnections to the individual pieces of rf hardware from the control system are made from the contacts at the rear of the card rack. Provisions should be included in any control system for expansion; the use of individual cards for specific circuits facilitates this goal.

New designs for amateur-built components should be breadboarded and thoroughly tested on the bench before being constructed in final form. In testing, provisions should be made for checkout of the new designs under conditions of continuous duty in temperature and humidity extremes. Fig. 33-2 shows a typical remote base station.

One other design feature should be included in any remote base: "series audio." This is illustrated in Fig. 33-3. In a series-audio system, the remote-base vhf receiver runs continuously, even when the control operator transmits; his speech is sent from his 450-MHz control transmitter to the 450-MHz remote base receiver and is then transmitted by the remote base vhf transmitter. The vhf receiver remains on, and although not connected to an antenna during this time, still receives a signal from the vhf transmitter operating nearby. Ths signal is retransmitted back to the control operator over the 450-MHz downlink. The control operator can listen to his voice as it is being transmitted on vhf by the remote base and can verify that the vhf transmitter in the remote base is being properly modulated. The speech from the control operator follows a path from the control-station microphone back to the control-station loudspeaker, with the remote base vhf transmitter and receiver in "series" with the duplex control link.

**Touch-Tone* is a trademark of American Telephone and Telegraph.

OPERATING A REMOTE BASE

What can be done with a remote base is limited only by the imagination and ingenuity of its owners. First and foremost, however, southern California remote bases operate on the area's simplex channels: many can be heard on 146.940 and 146.760 MHz. This is the historical rationale for the establishment of a remote base; and in fulfilling this function, remote bases have helped to remind fm operators—in a time of rapidly expanding numbers of repeaters—that much good work can be accomplished on a point-to-point simplex basis. Occasionally a remote base will be used to transmit bulletins of interest to the regional fm community on 146.940 MHz (a channel that every fm operator can monitor). With their height advantage, many southern California remote bases can be heard from Santa

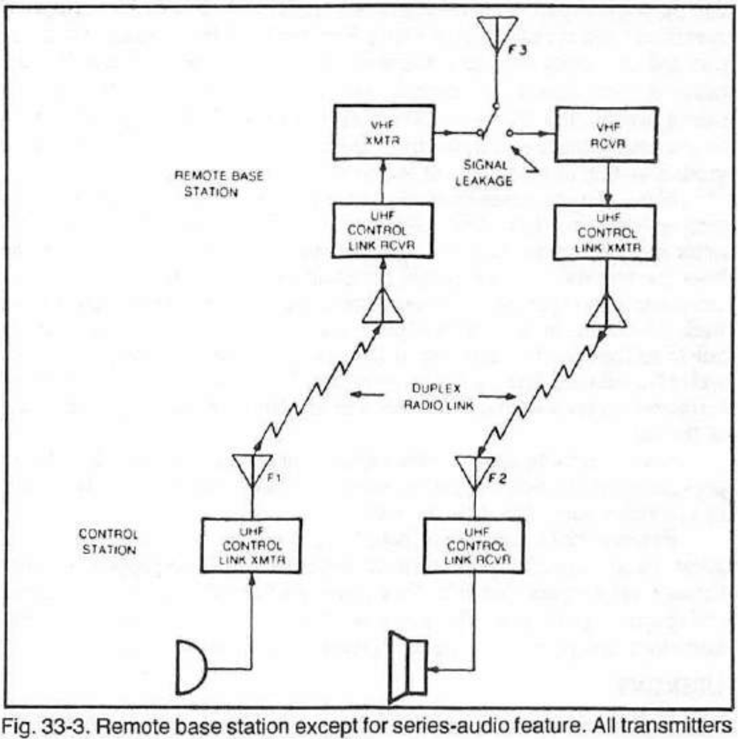


Fig. 33-3. Remote base station except for series-audio feature. All transmitters and receivers operate simultaneously.

Barbara to the Mexican border; they provide an invaluable resource for tying together an entire region by radio.

Because of the large number of remote bases in southern California, an agreement has been reached that use of 146.460-MHz simplex channel will be limited to an "intercom" channel among remote bases. This allows two or more remote bases to avoid monopolizing 146.760 or 146.940 MHz, which would prevent mobiles and home-base stations from using these channels. This arrangement has worked well in practice. A number of remote bases also have provisions for operating on 52.525 MHz and 29.600 MHz, the National simplex frequencies for these bands.

While it's possible to equip a remote base to transmit on a repeater input channel and listen to the corresponding repeater output channel, such practice is not often done. An exception would be where the repeater to be contacted is so far from the majority of the remote bases' control operators that they couldn't transmit on vhf directly into the repeater from their locations.

Several remote bases have been equipped with hf ssb transceivers. Notable was the former WA6ZRB remote base, which contained provisions for transmitting on 40 meters including remote tuning of the transceiver vfo. The remote was often used by control operators to check into the WCARS net.

Many remote bases contain autopatches. The use of a remote base for this purpose is particularly fortuitous because it removes the autopatch operation from repeaters in the busy 2-meter band thus reducing congestion and increasing repeater availability for mobile users. Generally, because of nonavailability of telephone lines at the remote base site, a special pair of auxiliary link channels operating in the 420-430 MHz region are used to transmit control-link audio from the remote base site to a telephone ground station at a convenient location.

Many remote bases contain auxiliary uhf radios, which link to other remote bases in other areas. Often two or more remote base groups will enter into reciprocal operating agreements, so that by means of the radio links the members of one group, transmitting through their own remote, can control and operate the other remote bases. For example, the Gronk Radio Network can be activated so that stations in southern California can talk to and operate through remote bases in central and northern California, and in Nevada and Arizona (and vice versa). This is an area where advanced fm operators are awaiting FCC rules and regulations to catch up to the state of the art.

Several remote bases contain special functions, such as telemetry of prevailing environmental and equipment conditions at the remote base site, or television surveillance of the site.

Remote bases have participated in emergency activities. With their great range and ability to contact virtually any fm-equipped amateur through vhf simplex channels, they provide a natural focus for emergency and disaster operations. The use of remote bases to relay traffic accidents and other emergencies to public agencies is a common occurence.

LICENSING

Before adoption of Repeater Docket RM 18803, remote bases were routinely licensed by the FCC after the required showings had been submitted. The FCC, then as now, wanted to be convinced that the remotely controlled station would not be tampered with or operated by unauthorized people, and that provisions had been made for automatic shutdown of the transmitters should be a failure of the control link occur. Remote-base license could be single "additional station" licenses, or primary-station licenses with authorization for remote control. Control operators required no special licenses but were listed as control points on the remote base license.

Southern California remote-base operators became concerned with the status of licensing after the adoption of RM 18803. Apparently under the misapprehension that only a handful of remote base licenses would be requested, the FCC devoted its time to the increasing number of repeater applications. But along the way, they released a set of "interpretations" of the new Part 97 rules, which completely changed the nature of remote-base operation.

The interpretations included a requirement for a) the licensing as auxiliary-link stations of all uhf transmitters that carry speech to and from the remote base, b) the licensing as control stations of all uhf transmitters sending control information to the remote base, and c) the use of separate uhf frequencies for remote base speech and control uplink channels. A subsidiary effect of these intrepretations was to declare as "illegal" the operation of the remote base from portable and mobile locations since, by definition, auxiliary links must operate between two fixed points. The FCC has since dropped the requirement that separate channels must be used for speech and control uplinks.

Nevertheless, remote-base operators are faced with a cumbersome and expensive licensing procedure and with operating restrictions more severe than those before RM 18803. The current licensing procedure, under which the FCC is processing and issuing remote base licenses, is as follows:

The mountaintop remote base must be licensed as a "secondary station" or "club station." This basic license covers the hf and vhf portion of the station; an "auxiliary link" license is required to cover the uhf down-link transmitter. Both priviledges may be combined on a single station license for a single application fee. Each control operator must modify his primary station license to include both "control station" and "auxiliary link" priviliges; this also can be accomplished with one application fee. The FCC has deleted the requirements for submitting many parts of the required showings, making them instead a required part of the station log.

During the ensuing years the FCC has come to better understand the remote base concept, and has shown increasing willingness to allow remote base (and also repeater) licensees more latitude in the operation of their stations. Docket 21033, which is based in part on a Rule Making petition by the authors of this article, if adopted, will grant essentially complete freedom to operate remote-base stations in the traditional ways described above. For example, Commission restrictions against operation of a remote base from portable and mobile control locations will be eliminated, licensing will be greatly simplified, and the distinction between the remotely controlled base station (with its associated control operators) and the true repeater will be clearly drawn. Southern California remote base operators are generally pleased with the contents of the Docket, and are looking forward to increased flexibility and freedom to innovate.

Remote bases are completely different in intent and operation from repeater stations. Repeaters are operated to extend the communications range for operators of specific mobile and hand-held portable stations interested in communications among themselves. Remote bases are operated as *extensions* of the owners' personal stations for purposes of communicating with *all* amateur stations. Almost all users of repeaters are *not* control operators, and the act of activating a repeater by transmitting on its input channel is *not* an act of controlling the repeater. Repeater control station operators are responsible for activating the station to repeat the transmissions of other amateurs and for suspending operations in the event that FCC rules are not complied with. By contrast, in southern California, every user of a remote base station has been a control operator. The remote base must be commanded by the control operator through the uhf radio link to operate for each transmission; it is not designed to *automatically* retransmit signals.

The comment has been made that, because the operation of a remote-base station involves speech transferred between hf-vhf and uhf frequencies, the remote base operates as a crossband repeater. From the discussion above it should be clear that the remote-base station does not fit basic definitions of a repeater. The act of monitoring a vhf channel through the remote-base vhf receiver and uhf downlink channel is not an act of repeater usage. The system *could* be used as a crossband repeater if a) two nonremote base simplex stations were to transmit on a channel being monitored by a remote base, and b) each were to listen to the other through the remote base 450-MHz downlink instead of directly on the vhf channel. In practice this seldom happens; if it should happen it is the responsibility of the remote-base control operator to suspend operations on that vhf channel.

It is our feeling, which is shared by a majority of southern California remote base operators, that liberalization of the present FCC rules (and interpretations of these rules) is required. Ideally each remote base could be licensed as a remotely controlled station, with one license covering the entire mountaintop station including the uhf radio links. Each user would be required to be an authorized control-station operator, having control-station privileges added to his primary station license. There would be no limit to the number of control stations that could be *conveniently* licensed including other remote base stations operating as control stations (many remote bases have 15 control operators at present). The control-station license would confer the privileges of both controlling and operating the remote base and would be usable in portable and mobile operation in addition to its customary fixed-station use. Were these proposed changes to be adopted, remote-base operators would achieve more flexibility to innovate in the amatuer vhf and uhf bands.

For those vhf/uhf-oriented groups wishing to expand their interests from individual circuits and individual stations to building an entire communications system, the remote-base concept has several advantages. It offers the chance to experiment with systems engineering - to design and build a system constructed from individual pieces of equipment. The final system can reflect the designers' needs, wishes, and abilities, rather than the standardized requirements of the marketplace. The remote base offers reliable, interference-free local communications capability on the vhf bands, thus helping to relieve congestion on the crowded hf bands. It abolishes the need for duplication of radios between home and car, or duplication among several cooperating owners, and permits the establishment of high-power transmitters and large antennas at the remote-base site. It fosters spectrum conservation on popular bands by removing the requirement for dedicated repeater channels, substituting instead the need for a dedicated pair of channels in the far-less congested 420-450 MHz band. It promotes the use of simplex communications, thus reducing the load of busy repeaters.

Southern California amateurs developed the remote-base concept more than ten years ago. It has proved to be a useful adjunct to the amateur vhf community. We look forward to its adoption in other parts of the country.

THE ROAD TO A REMOTE BASE

The term "Remote Base" has been defined and explained quite adequately in the foregoing section, so that it will not be duplicated here, except to say that you should have read that section, and understood the purposes, possibilities, and limitations of a remote base before continuing.

Implementing a remote base into an existing repeater is fairly easy, although the degree of ease will vary with the design of the present system—here again a bit of forethought helps.

A few years ago, the author received a letter from a friend in the midwest. He and his group requested anonymity, so we'll call him "Bob." Bob had a problem: A friend of his had put up a 2-meter machine, but due to the local geography, Bob couldn't use it, either from his home or his job. The only time he could talk to his friends was during the drive to and from work.

The solution was simple—a remote base, located at a site that covered home, job, a useful local area, and the 2-meter machine of interest. The idea, a system block diagram, and some supportive material (including much of what is in the *ham radio* magazine article reprint) was mailed. Back came a letter, "Let's do it!"

Bob found four more hams who were interested, including the local CB & Two-Way tech, who we'll call "Tom." Enough Clegg FM76 rigs were purchased to outfit everybody, with two extra for the repeater. One of the other four was assigned the job of group "Politican;" he would take care of the site agreement, coordination-council paperwork, and generally anything having to do with outside paperwork. Another one was assigned the job of 'Equipment;' he took care of the Clegg purchase, crystal ordering, parts acquisition (integrated circuits, transformers, and other parts). Tom was the builder—he would do all the electronic work. If he needed parts, the equipment man would get them. Another person was assigned the job of "Antennas;" he would build the system antennas, keeping in mind that durability, reliability, and performance is more important than looks. The antennas ended up looking like a plumber's bad dream, built inside thick-wall PVC high-pressure water pipe, but after over two years of midwest weather the performance has not degraded a bit.

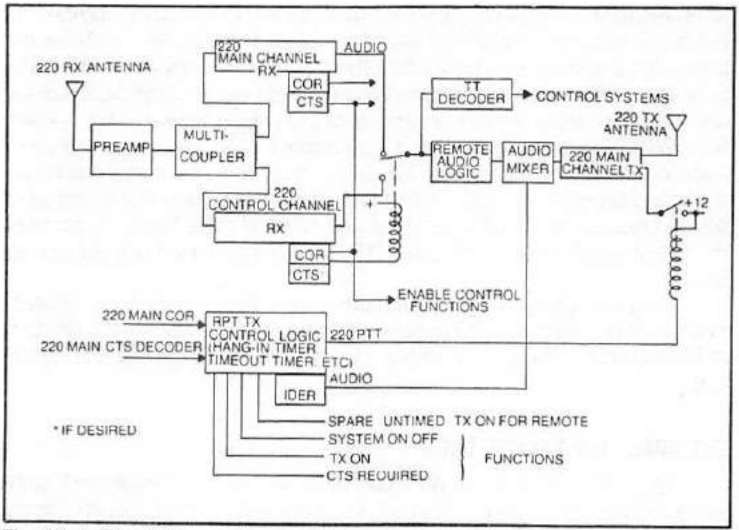


Fig. 33-4. The 220 repeater.

The politician came back with some interesting information from the coordination council: There was almost no 220 activity, so let them know what channel we would like! The decision was made, and the channels were assigned, along with a control channel. While all this was going on, Tom was busy converting a Clegg into a repeater, as described in an earlier chapter. This repeater was installed, with a direct wireline to Bob's house for control (his wife was at home 99 % of the day, and she was a ham also; she could turn the machine off at any time if necessary). The second Clegg had not been dismantled and the receiver converted into the control receiver as yet. Also, Bob, the trustee, felt a lot better knowing that an extra control method was available. Besides, if he wanted to pay for the phone-line pair out of his own pocket after the radio-control receiver was installed, Tom was quite willing to include the wireline panel in the radio-control logic. Up until that time, the telephone-line fee would come out of the club treasury.

The antenna man had completed his job, so he was given the task of constructing the "small, simple, stuff" that goes into any system: the IDer, or the audio mixer. The IDer was programmed with Bob's call, with a "/AUX" suffix instead of the normal "/RPT." This was due to the fact that this system was intended as a remote base, not a repeater.

The basic repeater was complete, and installed at its site, and used quite heavily during the following month. A couple of minor problems showed up, and were corrected. The basic repeater system is shown in Fig. 33-4.

During the month, a old Regency HR2 was picked up, and a 2-meter antenna was constructed and installed at the site. The touchtone decoder was constructed, along with enough sequence decoders to handle all of the wireline functions, and some extra as well. The decoder and logic was installed, with the wireline having priority over the touchtone logic. The control receiver was converted and installed.

The control receiver was wired into the system to "take over" the control logic, allowing one Touchtone decoder to be used by both receivers. A number of functions were also "enabled" by the control receiver COR, preventing users from activating things that they shouldn't. Later on, a CTS decoder on the main-channel receiver enabled these functions, in case the control receiver ever died, and nobody was home at Bob's to shut things down by wireline.

While Tom worked on the control logic construction and installation the Regency modifications were completed. These consisted of adding an extra connector and circuitry to route receiver audio, transmitter audio, PTT, COR, power, and ground through one plug.

The control logic included the remote-base logic, so as soon as Tom was happy with the controls, the Regency was installed. The remote-base interconnects and logic are shown in Fig. 33-5.

The design problem has been solved: Bob and his friends have a quiet 220 intercom repeater, along with a 2-meter remote base. But, along with this, some individuals have ideas for improvements. The politician wants to add weather and WWV receivers. Tom wants to add 20-meter, just to prove to a local "20 meter-die-hard" that it can be done. Bob's wife wants an autopatch (after all, the Touchtone dials are already installed, why can't I make a phone call from the car?), and Bob himself wants to remote control the channel switch in the Regency—after all, it is a six-channel radio...

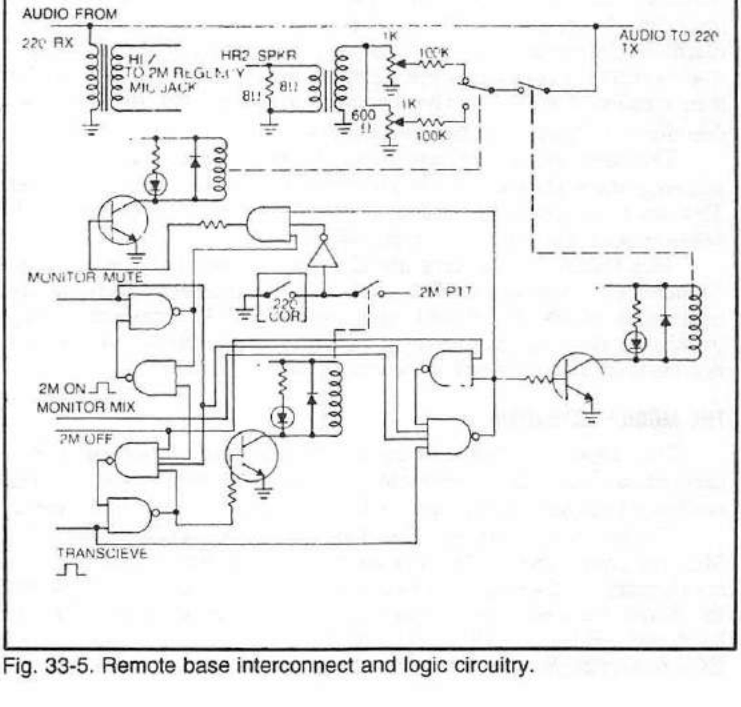


Fig. 33-5. Remote base interconnect and logic circuitry.

SILENT MONITOR, MONITOR MIX, AND MONITOR MUTE

When a remote base is in the 2-meter listening mode, and the 220 (or 440) MHz input opens up, what do you do with the 2-meter audio? Do you leave it alone to compete with the 220 audio, do you cut it down, or do you turn it off completely?

If a flat decision is made, it later proves to be the wrong one. That is why most of the remote bases have taken the selectable route—they provide two modes, user selectable.

In the Los Angeles area, "Monitor Mix" mode is one where the 2-meter (or whatever) audio is at normal amplitude until a carrier arrives on the main-channel input. At this time, the 2-meter audio is reduced to a level where someone who is interested in the 2-meter conversation can follow it, while ignoring the 220 conversation between two other users. This level is about 25 percent of normal.

"Monitor Mute" mode is one where the 2-meter audio is muted completely when 220 becomes active.

"Silent Monitor" is a less popular technique. It can best be described by giving an example. Let's say that the 2-meter section of our remote is turned off, but someone on the local repeater wants to get in touch with one of the people on that system. How does he do it?

A second Touchtone decoder attached to the 2-meter receiver could insert an audio tone on the 220-MHz transmitter, alerting the users that someone on 2-meter wanted someone on 220. The secret here is that when the users "turn off" 2-meter, they don't really kill it. The 2-meter receiver power is left on, and just the audio is turned off (and connected to the touchtone decoder). If the system has more than 1 channel on 2 meter, it would revert to a known channel. This channel should be a repeater, rather than simplex. It should also not be an autopatch system, to prevent the decoder from falsing on dialing sequences.

The silent-monitor system should have a disable function, in case someone starts playing with his Touchtone pad on the 2-meter repeater. This can be as simple as turning off the 2-meter receiver power, or the silent-monitor Touchtone-decoder power.

This feature can be very useful if your remote is to be used as a "2-meter extension radio." The instructions for the use of silent monitor can be as simple as: "If you want to get on the WB6SOX remote base just go over to the 16/76 machine, and hit *SOX on your touchtone pad. If anyone is around on 220, they will answer in a couple of minutes."

THE MOBILE EXTENDER

The chapter on remote bases wouldn't be complete without a short description of one of the cleverest ideas around—the mobile extender. This is a fancy term for a mobile remote base, contradictory as it may seem.

The basic idea is simple. "Joe Ham " has a 2-meter hand-held, a 220 MHz hand-held, and a 220 and a 2-meter radio in his car. He finds that occasionally, his 2-meter hand-held just doesn't have the push to get into the 2-meter machine. So, he crystals up one channel of his 220 MHz hand-held and his 220 MHz mobile on some obscure 220 channel, adds a COR to his 220 mobile, and then hooks the COR and audio to the 2-meter rig. (The most common way is to have a substitute mic plug—unplug the 2-meter mic and plug in the 220 radio.) Now, he talks on the 220 hand-held, and listens on the 2-meter one. He has the power and better antenna of the mobile, with the portability of a hand-held. The only problems are: two hand-helds are needed, and there is the possibility of a dead battery in the mobile.

The hand-held problem can be cured by carrying the complexity one step further. Use the "sampling" idea of the simplex autopatch on the 220 channel, rebroadcasting 2-meter back on 220, and sampling to see if you have pressed your mic button. If you have, key the 2-meter transmitter. Motorola has had a mobile extender on the market since mid 1978, using this technique under the name "PAC-RT (commonly called "Pack-rat"), or more formally "Portable/Mobile Vehicular Repeater System". The manual has an excellent description of the techniques used. Using this technique, you could carry one 220 hand-held, and hear everything on the 2-meter channel, rebroadcast from your car. You could talk back to your car on 220, and come out on 2-meter. Make sure you have an IDer on the system—You have just built a repeater.

THE MAGIC ELECTRIC AMMO BOX

The system described in this section was designed as a "remote base" which incidentally has a 220 MHz repeater as its foundation. If the 220 repeating function is not needed, then there is a simpler solution to the "I can't work the repeater from my house" problem.

The basic idea is shown in Fig. 33-6. It is simply a 220 radio and a 2-meter radio back-to-back. This technique can be reduced to utter simplicity very earily. In fact, the author knows one ham that has such a setup built inside a surplus US Army .50 cal ammunition box. Just add a car battery, and screw two Motorola antenna spikes (2-meter, and cut-down-2-meter on 220) onto mounts on top of the box. The only control is an on-off switch. It is frequently used on special-events (parades, marathons, walk-a-thons) where one particular area has coverage problems. Note, however, that the incoming carrier has to go completely away before the system can "turn-

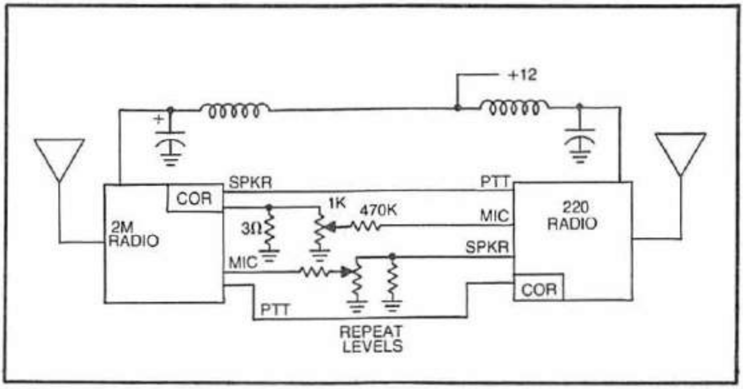


Fig. 33-6. A simple remote-base can be made from a two-meter and a 220-MHz transceiver hooked "back-to-back."

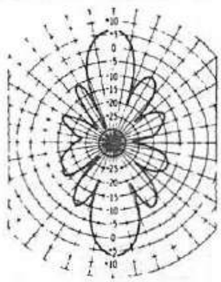
around." This would not work on a repeater that uses a constant-carrier and a reset beep.

Also note that the system can be used to interconnect a 2-meter repeater to a 220 MHz repeater, or a 2-meter simplex channel to a 220 simplex channel, or whatever your heart desires.

Also note that there is no IDer—the schematic shown is simply that of the "Magic Electric Ammo Box"—the owner identifys the unit by voice every 10 minutes of use.

The unit has proven it's worth many times at various special events, and has more than paid off its cost —$3 for the surplus ammo box, $50 for a used Clegg FM76, and $25 for a old Tempo FMV. A 20 Ah Nicad battery was picked up in surplus for $30. The antennas were picked up at a swap meet for $5 each. The unit is used most of the time as a mobile extender.

Chapter 34
ATV Repeaters



There are two types of fast scan ATV repeaters in use today. They are inband, using the input and output in the 420 to 450 MHz band, and cross-band, using input on 420 to 450 and the output in the 1215 to 1300 MHz band. ATV repeaters are more difficult to build because the standard television bandwidth is 6 MHz. Until now, with the 7 pole interdigital filter, ATV repeaters had to sacrifice sound and color subcarriers in order to use filters that had enough rejection of the transmitter noise that desensed the receiver.

THE FIRST ONE

The first dedicated ATV repeater was built by Bruce Brown, WA9GVK, and the Metrovision group in the Washington, D.C. area. It had to go on under a special temporary authority in 1973, as it used 439.25 in and 427.25 out, which was out of the repeater band in those days. Much of the gear then used by ATVers was converted FM rigs, and the core of the repeater was a Motorola T44. To get around the sound problem, since the T44 only had a modulation bandwidth of about 3MHz, and the sound subcarrier is at 4.5 MHz, they used the FM modulator, since it was essentially free. With this system, you had to add an FM receiver to get the sound. The repeater transmitter is actually putting out both A-M (video) and FM (sound) at the same time.

Today WR4AAG is solid state, except for a CRT in the TV carrier monitor of course. There is a dedicated computer at the repeater site that can be accessed on the sound input. They can execute programs through the repeater using a keyboard and tone generator, similiar to teletype. One program puts 3 digits on the screen that corresponds to the received signal strength at the repeater. This is great for checking out antennas, etc. In southern California, ATV went crossband to 1240 for two reasons. The band was so rapidly filling up in the late 1960s that only one wideband frequency was available. Secondly, it was so much easier to keep the filters simple and not restrict the bandwidth at the same time. About 6 stations could repeat 434 MHz on 1240 MHz when requested. A dedicated repeater did not seem necessary, as temperature-inversion skip often gave good pictures over 100 mile paths. Stations below the layer could do better than a station on a hilltop. Typical range, with 10 watts simplex, in this desert area was 50 miles, where in the midwest it might be 15 miles. Trees and foliage have a high absorption rate at 400 MHz, so, as long as the antenna was

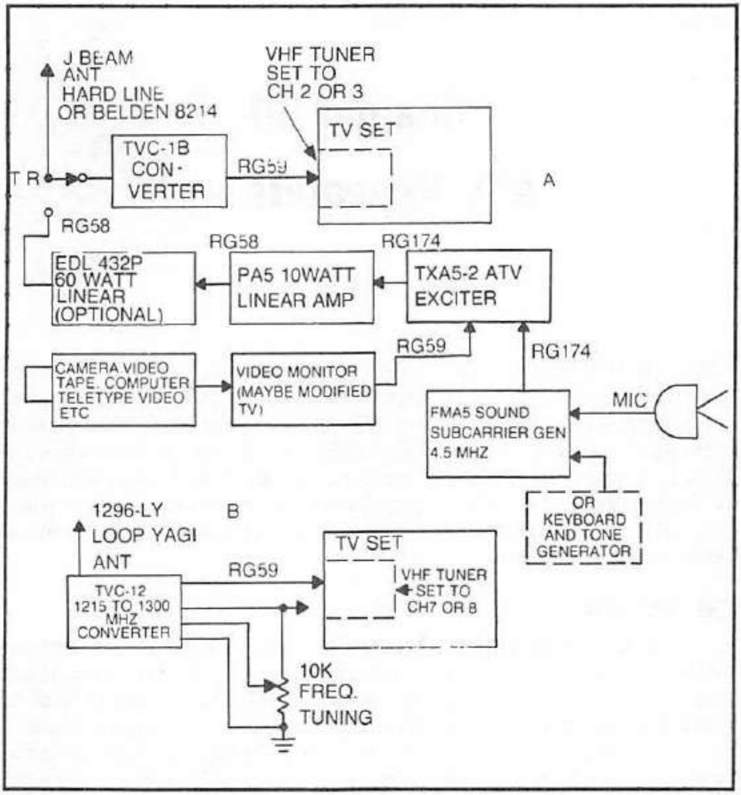


Fig. 34-1. Repeater user's ATV station. Modification to receive 1215-MHz ATV is shown at B.

above them and it was a little smoggy, the DX might be very good. With the bandwidth somewhat unrestricted, the pictures, expecially color and computer graphics, could be better than commercial broadcast TV. With the popularity of microcomputers, there is now a dedicated crossband repeater up with plans to put a Radio Shack TRS-80 at the site. This would serve many users with a cost of about $50 for a keyboard and tone generator.

SPECIALIZATION

There are some specialized repeaters in use in Tulsa, Oklahoma, and Indianapolis, Indiana, that are used to televise the weather-radar video to hams and emergency organizations during tornado season. Warren Weldon, W5DFU, was the first to realize the benefit of adding sight as well as sound for public services. Other uses are at parades, walkathons, CAP searches, and races. Basically, fast-scan ATV can do anything that broadcast TV can do, since the same basic standards are used, and most hams already have the receiver—a TV set. Only a simple receiving converter to bring 420 or 1265 down to channel 2 or 3, and an antenna must be added.

Fig. 34-2. ATV repeaters can be configured to provide many services to the user.

ATV is growing in popularity such that there are two companies offering ready-built repeaters, others with complete base-station transmitters and converters, and one with modules for the build-it-yourselfers. A5 Magazine (7391 W. St. HWY 46, Ellettsville, IN 47429) is dedicated to both fast- and slow-scan ATV, and is probably the best continuing reference on this mode. Any closed-circuit TV camera, and most home video-cassette recorders can be used directly for transmitting pictures. A block diagram of a repeater you can assemble in modular fashion is shown in Fig. 34-1. Other ATV repeaters are shown in Figs. 34-2 and 34-3.

As with any repeater, the first thing to do is site selection. If the users can't work the site, there is no sense putting equipment there. The terrain is such a big variable that line-of-sight calculations may prove worthless. The best thing to do is to arrrange with some local stations for reception tests and try a portable transmitter at the selected site. Antenna height is more important than power. One item often forgotten in line-of-sight

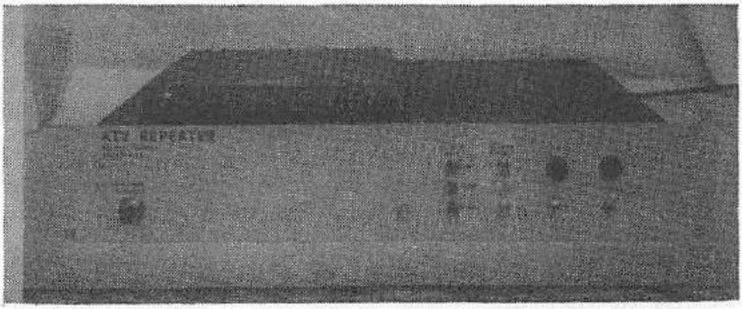


Fig. 34-3. The P.C. Electronics ATV Repeater package.

calculations is the fact that it's not necessarily the antenna tower height, but the height above the level where the absorbing foliage and structures are that counts. An antenna on a 50-foot tower may be only 25 feet above the real RF ground. Polarization is generally vertical, since it is much easier to get omnidirectional gain antennas and separation with these than with horizontal ones. There has always been much discussion on the subject, but an U.S. Army study concluded that there is little difference above 300 MHz as to polarity for reliable communication. It also said that, below 300, horizontal was more reliable. The important thing, of course, is that every user run the same polarity.

BANDWIDTH

Bandwidth is an important factor with ATV. If a Phelps Dodge Super Stationmaster is ordered for the repeater, make sure you request that it be specially selected such that the maximum gain and minimum VSWR occur at about 1MHz above the video carrier. The PD-455 is probably the best antenna to use, and gives about 50 dB of isolation between the receive and transmit frequencies when two are separated at least 10 feet. This antenna has about 10 dB gain. A lower cost alternative is the Cushcraft 4 Dipole array with about 5 dB gain. For 1265 MHz a coaxial collinear may be made from brass hobby tubing and brass ⅛ inch welding rod, to give about 7dB gain.

To keep the transmitter from desensing or locking up the receiver, good hard line or double-shielded coax must be used down to the bandpass filters. To get the most rejection, the frequency separation must be as wide as possible. The inband standard seems to be input at 439.25 and output at 425 MHz. It has been proposed that, since the 7-pole interdigital filters attenuate the lower sideband color and sound subcarrier component at least 40 dB, that 421.25 become the standard output. With this separation, the filter has more than 80 dB rejection of the unwanted video carrier. For crossband, 434 in 1265 out seems to be most used, unless 1265 is used for trunking from a 439 in 421 MHz input. Cross-band has the advantage in that the receiving stations can see their own video coming back, or go full duplex, since simple filters can be used. This a natural for interactive computer games. 146.43 is the national ATV coordinating frequency that is used to talk with pictures, or comment at the same time with the audio from the ATV transmitting station. Two meters is also being used on a repeater in the Baltimore, MD, area to control the paddles on a video pong game by use of tones.

The receiver must be well shielded and crystal controlled. It makes no sense to go to great pains to filter out unwanted signals just to have them sneak past into the converter. Select modules or a TV set that has a wide AGC range to handle both the close and distant stations it will probably encounter. Tap into the video detected output before the sound trap, as you want the sound to be retransmitted. The sound output can be routed to special control-function decoders or computer AFSK decoder. It's a good idea to do some temperature testing of the system, or keep it housed in a temperature-stable enclosure.

CONTROL

The control circuitry can be similar to most repeaters, with the addition of a 15,750-Hz tone decoder so that the repeater is only keyed on

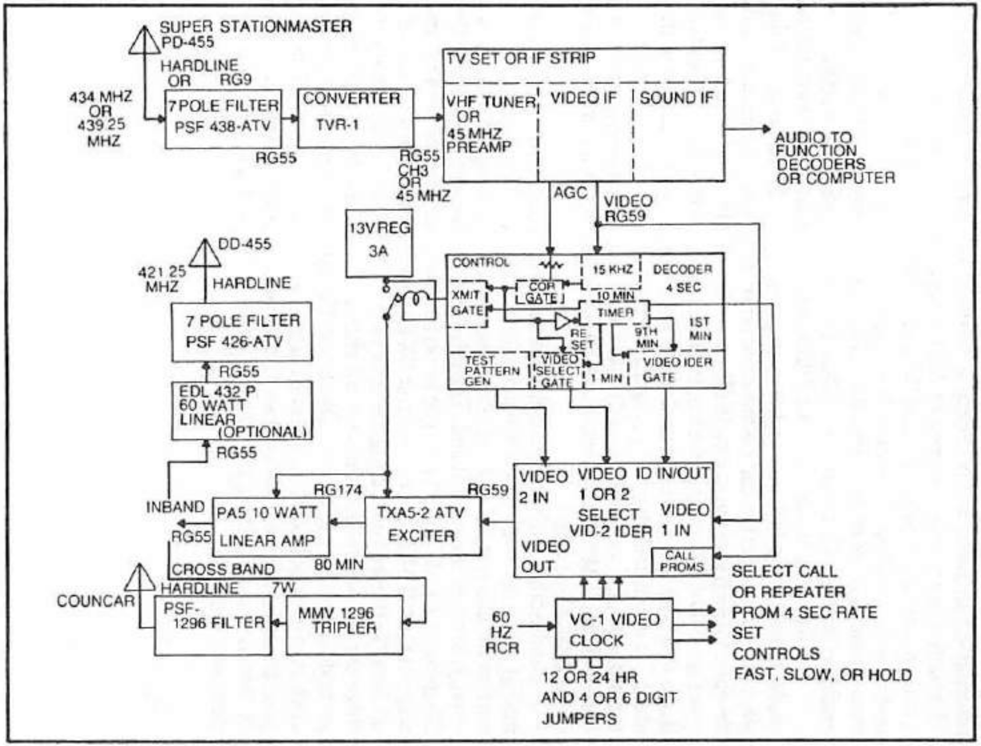


Fig. 34-4. Block diagram of an ATV Repeater. The tripler is used for output on the 1215-1300 MHz band.

by a TV signal. The 15,750 Hz comes from the horizontal sync. The sync-decoder output can be gated with the AGC COR so that FM, radar, or noise will not accidently key up the repeater. As far as interference, other users usually cause more problems for ATVers than the other way around. Video sidebands are more than 60 dB down greater than 1 MHz away from the video carrier. Tests with AMSAT, running the OSCAR mode J on 435 MHz while running ATV on 434 MHz, gave no interference to oscar users, but put lines in ATV pictures. Before firing up the repeater it's best to check with the local frequency coordinator or users, and make the test for sync buzz or TVI.

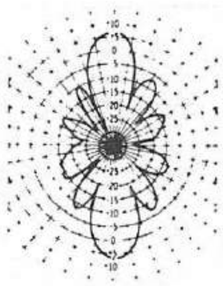
The example shown in Fig. 34-4 is for the southern California crossband repeater, with the only difference for inband being the 7-pole filter and no tripler on the transmitter. The transmitter must be filtered to keep the wideband noise out of the receiver passband. Double sideband is transmitted on 1265, and by filtering, vestigial sideband on 421.25 MHz. The control timing was designed so that the repeater drop-out time is about 1 minute, with a test pattern, video ID, and clock to enable users to do some testing and tweaking if desired. Maximum continuous time is set for 10 minutes and will not reset unless the video carrier is dropped. Modules are available from P. C. Electronics, 2522 Paxson, Arcadia, CA 91006.

The path loss at 1265 is about 7 dB more than at 434 MHz. But, this is made up for by the fact that higher-gain antennas can be made at 1/3 the size, and the converter can be mounted on them to save the coax loss. A 29-element loop yagi measures 18 dB gain over a dipole. The boom length is less than 7 feet. The converter has an output on channel 8, which results in much less loss and better overall noise figure than if it was placed in the shack . It is remotely tuned by a varicap in the oscillator. The selectivity of the antenna and converter is such that a weak signal showed no interference from the 434 MHz transmitter at 10 watts, as long as the antennas are more than 3 feet apart.

Bandwidth is an important consideration at the repeater user's end, for inband types as well as crossband. Most high-gain Yagi types are too narrow for efficient TV use. There are some that are designed to be broad enough to cover the whole band. These are the 48-element J Beam, and the 27-element KLM. The F9FT type is too narrow to accommodate 439, and way out for 421 MHz. The Cushcraft DX420 is good for 434 or 439, but falls off for 421. Before connecting the coax to your ATV converter, make sure that your TV set does not have a hot chassis. The coax shield is probably grounded through the tower. Check the TV with an ohmmeter from the chassis to each side of the ac line cord (unplugged!) out of the set. If it is hot, you can either add an isolation transformer or capacitively couple each side of the coax lead coming into the TV tuner with .001 μF, 500-volt disc ceramic capacitors.

Chapter 35

RTTY Repeaters



When we think of relay devices, particularly FM Repeaters, we think primarily in terms of voice communications. However, we are very shortsighted to think that voice must be our one limitation. Within reason, virtually anything that can be transmitted can also be relayed. Consider radioteletype; the "Green Keys" as the RTTY boys call them. In the same way that voice is relayed, so can RTTY be repeated.

Arny Gamson, K6PXA, is a RTTY buff, also a very involved Amateur. Employed by Union Oil Corporation as a Communications and Microwave Technician, Arny spends much of his free time totally immersed in his favorite hobby, Amateur Radio. Holder of an Advanced class license, Arny is at home on HF working DX as he is in a local roundtable on one of his favorite repeaters. However, Arny's first "Amateur Radio love" is RTTY, and he not only operates the mode, but acts a editor of "Scatter," the monthly newsletter of the Southern Counties Amateur Teleprinters Society of Southern California, and is also VHF Editor of the *RTTY Journal*.

With Arny's assistance, we have put together some interesting material for you to feast your eyes and mind upon. With thanks to the *RTTY Journal*, PO Box RY, Cardiff By The Sea, CA, we present the following on RTTY in relay service.

We often hear "How does one set up a (RTTY) repeater?" The answer is about as simple as "How high is high?" I would like to relate our Southern Counties Amateur Teleprinter Society (called SCATS) experiences in this endeavor. Some of it is unique to our location and situation the rest you can benefit from our experience, good and bad. The first step is to secure a site. In Southern California we are dotted with lots of mountains up to a mile high providing maybe 100 miles or more range (200 mile portal to portal). Unfortunately most of these sites are crammed with commercial and ham repeaters, and all the VHF and UHF frequencies are already allocated and crowded. 146.10/70 Mhz is the usual RTTY repeater frequency used by most, but not all, groups nationwide. It is recommended to have a guardband - (unused channel on each side) to avoid adjacent channel interference. The next step is to secure 6 major pieces of equipment; power supply, transmitter, receiver, terminal unit, duplexers and antenna. As a general rule, we would recommend securing the very best equipment you can get (commercial is usual). This to eliminate maintenance and interference problems.

The transceiver is a Motorola Mobile which now has a super-regulated-filtered IBM power supply. The "Motran" model is total solid

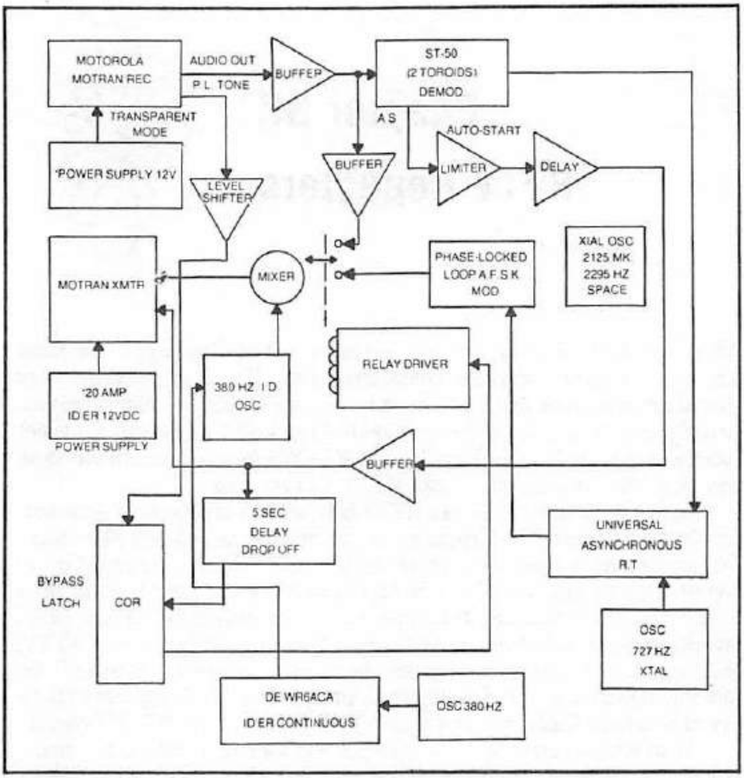


Fig. 35-1. Block diagram of the WR6ACA RTTY repeater.

state and is clean on a spectrum analyzer when transmitting alone. Unfortunately, RTTY with its readily identifiable tones, will cause other systems hearing them to automatically scream "Clean up your filthy Tx." A computer run of any potential mixes, and a spectrum analyzer check, are certainly desirable. Also keep the deviation of the AFSK tones from the repeater (as well as your own) to below 2; and run the RF power conservatively, as it may often be 100 percent duty cycle for many hours. Now we come to the "heart" of the entire system, the Terminal Unit. Unlike the ordinary voice repeater, RTTY requires the following: 1) Two-Tone audio decode of Mark (2125 Hz.) and Space (2295 Hz.) 170 Hz narrow shift. 2) Autostart. 3) UART clock regenerator operating at 727 Hz. for 60 WPM. 4) AFSK tone generator. 5) Repeater call sign IDer—a low frequency tone (approx. 400 Hz.) continuous or every ten minutes. It must not print, of course. The WR6ACA repeater has several embellishments which we highly recommend to avoid problems as we had: The UART clock and the AFSK are crystal controlled, and can be used as a standard reference; both are held constant within 1 Hz. Originally, we found they would both drift over 5%, causing problems. In addition to completely regenerating the tones, the repeater can be placed in a "Transparent" mode, allowing your input tones to go through direct. This mode is triggered by a sub-audible tone (in our case, 141.3 Hz). The main reason for regenerating tones is that we have found many of the input signals extremely off frequency poor quality, incorrect deviation etc., and they are cleaned up by the UART. Voice, and hopefully other garbage, should not get through either due to the narrow bandpass (2 to 2.5 kHz). Illustrated is a block diagram of the WR6ACA repeater system, Fig. 35-1.

The ingredients for a VHF RTTY station include a standard FM transceiver, a teletype machine, a terminal unit (demodulator), an AFSK

Table 35-1. Parts list for the RM 300 MODEM.

RM-300 RTTY MODEM PARTS LIST

Description	Reference	Quantity
Integrated Circuits		
XR-2211 FSK Demodulator (Exar)	U1	1
SN7410N Triple 3-Input NAND Gate	U2. U7	2
SN7400N Quad 2-Input NAND Gate	U3	1
SN7404N Hex Inverter	U4	1
SN7407N Hex Buffer/Driver	U5	1
LM339N Quad Comparator	U6	1
XR-2206CP Function Generator (Exar)	U8	1
XR-2240CP Counter/Timer (Exar)	U9	1
6330/N82S23 256-bit PROM	U10	1
SN74151N 8-Channel Mux	U11	1
SN7490N Decade Counter	U12	1
Diodes		
1N914 (or equivalent)	CR1	1
Capacitors (All microfarads)		
.01/50 V Disc	C1. 2. 10. 14. 19. 20. 22. 23	8
.1/50 V Disc	C3. 4. 17	3
10/25 V Electrolytic	C5. 6. 11. 12. 13. 21	6
.0022 Polyester Film	C8	1
.047 Polyester Film	C9	1
.01 Polyester Film	C7. 15	2
1.0/35 V. Electrolytic	C16	1
.1 Polyester Film	C18	1
Fixed Resistors (5%. ¼ Watt)		
680	R11	
5.6K	R4-8. 13-16. 19. 22. 25. 26 33-35. 38. 40-54. 563	3
100K	R2. 11. 24. 55	4
36K	R9	1
220K	R10	1
3.3 Meg	R12	1
100	R17. 20. 23	3
33K	(Optional) R18. 37	2
4.7 Meg	R21	1
39K	R28. 30	2
220	R29	1
560K	(Optional) R37	1
Potentiometers		
830-P-20K Weston	R3. 27. 31. 32	4
830-P-500K Weston	R36	1
Sockets/Connectors		
14 Pin Solder Tail IC		8
16 Pin Solder Tail IC		4
22/44 Edge Connector (.156 Centers)		1

oscillator (modulator), and a means of sending your call in Morse code as required by the FCC.

A MODEM

The RM-300 Modem (Modulator-Demodulator) was developed to provide a simple way for those interested in VHF RTTY to get on the air. The RM-300 contains a phase-locked-loop (PLL) demodulator to convert the 2125/2295 Hz tones from your transceiver's speaker terminals to Teletype keying pulses, a stable AFSK modulator to feed the microphone input of your transceiver, a read-only memory CW identifier, and autostart logic, all on a single 4½ × 6 " circuit board. A second board, the RP-400, contains loop and low voltage power supplies, and loop-keying circuitry.

A schematic diagram for the RM-300 is given in Fig. 35-2. The three major functions contained on the circuit board are grouped on the schematic. The demodulator portion is shown in the top third; the AFSK modulator is in the middle third and the CW identification circuitry is in the bottom third of the schematic. Detailed descriptions of connections to and from the RM-300 circuit board are given in Table 35-1, while a photograph of the board is shown in Fig. 35-3.

DEMODULATOR AND AUTOSTART

Audio from the transceiver is fed to the XR2211 PLL via pin 18 on the board edge connector. The PLL output on U1 pin 7 is at a TTL-compatible high level when the input tone is 2125 Hz (MARK) and low when the input tone is 2295 Hz (SPACE). The frequency at which the PLL switches from high to low is the PLL center frequency as determined by Center Frequency potentiometer. R3.

The PLL output signal is inverted by U4 and applied to the anti-space circuitry (U5 and U6-C) and the keying inhibit gate U2-A.

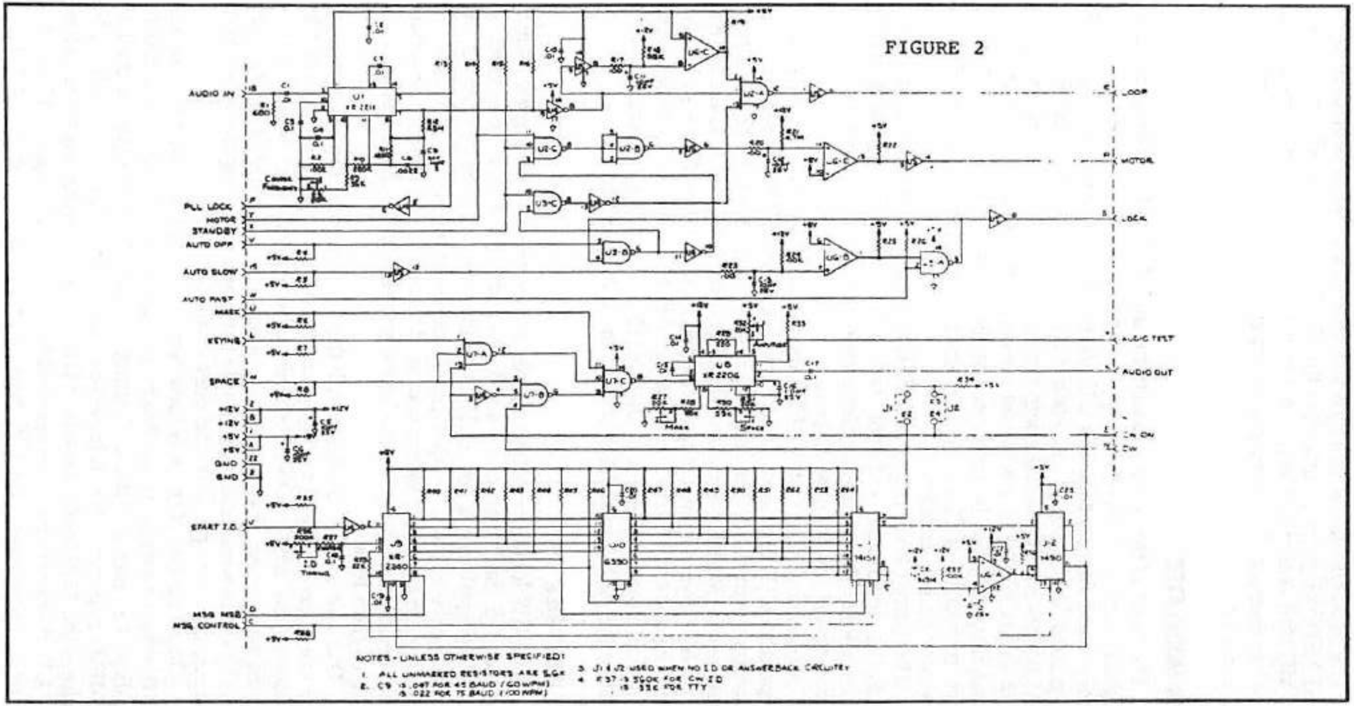
The anti-space circuitry prevents space tones longer than approximately 200 milliseconds from keying the loop. The output from U5 pin 2 clamps the voltage across C11 near ground as long as the PLL is detecting a MARK tone. A space tone allows the voltage across C11 to rise at a rate determined by R18. If the voltage rises above 5 volts, the output of U6-C goes low, which forces the loop into MARK-hold.

The autostart circuitry and the standby logic can be used to force the loop into MARK-hold. The PLL contains a carrier detector which has a TTL-compatible output on pin 5 of U1. This output is low when a signal within the lock range of the PLL is detected. The carrier-detect output, after inversion by U4, can be used to control the FAST or SLOW modes of the autostart function. The FAST mode allows the Modem to respond immediately to a detected signal, which gives sufficient noise immunity on VHF circuits. When a carrier is detected by the PLL, the LOCK output (edge connector pin 5) goes low. This output can be used to control LED on the Modem front panel.

If the AUTO OFF input (edge connector pin V) is grounded, or a carrier has been detected, and the STANDBY input (pin X) is high, the loop can be keyed by the PLL because pin 13 on U2-A is high.

The open-collector loop-output from U5 pin 2 is high for MARK and low for SPACE. It can be connected directly to a loop keying transistor or to the serial input of a UART.

FIGURE 2



NOTES - UNLESS OTHERWISE SPECIFIED:

1. ALL UNMARKED RESISTORS ARE 5.6K
2. C9 IS .047 FOR 45 BAUD (60 WPM)
   IS .022 FOR 75 BAUD (100 WPM)
3. J1 & J2 USED WHEN NO I.D. OR ANSWERBACK CIRCUITRY
4. R37 IS 560K FOR CW I.D.
   IS 33K FOR TTY

Fig. 35-2. Schematic diagram of the MODEM.

The MOTOR output (pin P) is low when a signal has been detected, the STANDBY input is grounded, or the MOTOR input (pin Y) is grounded. The MOTOR output will stay low for approximately 25 seconds after a signal has dropped. This timing is determined by the RC time constant of R21 and C12.

AFSK MODULATOR

The heart of the AFSK modulator is an XR-2206 Function Generator integrated circuit. It produces low-distortion sine-wave tones at a frequency determined by capacitor C15 and the resistance between pin 7 or 8 and ground, depending on the control input on pin 9. When pin 9 is high (MARK) R27 is used to set the output frequency to 2125 Hz, and when pin 9 is low (SPACE) R31 is used to set the output frequency to 2295 Hz. The output frequency can be monitored at the AUDIO TEST output (pin T) which provides a TTL-compatible square wave replica of the function generator output waveform.

The output level from the AFSK modulator should be adjusted to match the requirements of your transmitter audio circuitry using potentiometer R32. The output amplitude can be adjusted to a maximum level of approximately 5 volts peak-to-peak.

All control inputs to the AFSK modulator are TTL-compatible. The teleprinter keyboard signals are applied to the KEYING input (pin L). Consistent with the design convention used throughout the board, a high input yields a MARK tone while a low input yields a SPACE tone. MARK and SPACE override inputs are provided on pins U and M, respectively. These inputs can be used to force the AFSK modulator to either state despite information present on the KEYING input. The remaining control input to the AFSK modulator is from the CW identifier.

CW IDENTIFIER

The CW Identifier output signals include the CW keying line, which provides full shift keying, and a CW ON control line which precludes all other keying when it is active. The CW Identifier, started by momentarily grounding the START ID input (pin J), causes either "O" or "." characters to be printed by the receiving station. The timing and memory programming required to accomplish this format were described in the January 1974 issue of Ham Radio.

One new feature, available with the "O" option, is the ability to have two call signs in the read-only memory. One call sign is accessed by grounding the MSG CONTROL, pin C, while the other is obtained by leaving pin C open. If your call is too long to fit in one half of the memory (128 bits) the whole memory can be used by connecting the MSG MSB Output, pin D, to pin C on the edge connector.

On-off control of the CW identifier is accomplished with U9, an XR-2240, which contains as oscillator, an eight-stage divider, and a control flip-flop. The timing of the CW output is established by adjusting the I.D. TIMING potentiometer, R36. Five of the eight divider outputs from U9 address the 32 bytes of memory in U10, while the remaining three extract the CW characters from the selected bytes with multiplexer U11. Decade counter U12 monitors the CW input for consecutive "blanks", and after it

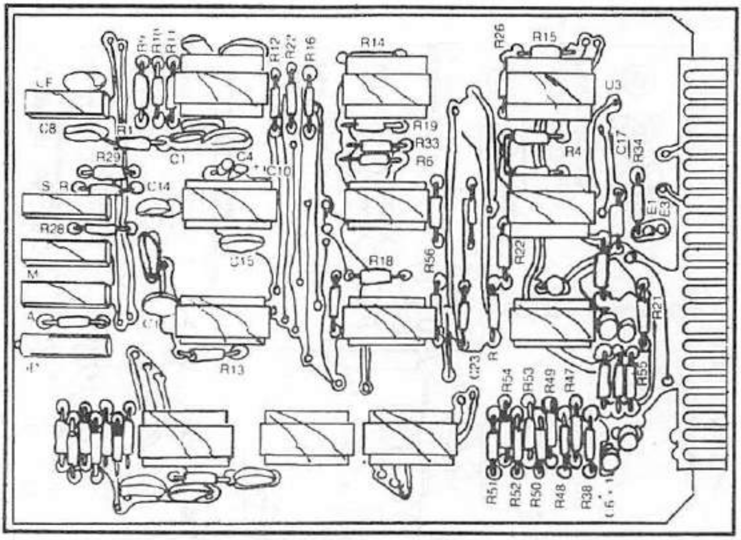


Fig. 35-3. The RM 300 RTTY MODEM board.

detects eight, turns off the control flip-flop in U9. Comparator U6-A and its associated circuitry resets the decade counter so the counter starts with the correct count when power is first applied.

ADJUSTMENTS

Proper adjustment of the Modem requires a frequency counter and a voltmeter or oscilloscope. The Modem can be adjusted with help from another station who has a counter or an AFSK oscillator/demodulator which is known to be calibrated.

AFSK Generator

Connect a counter to AUDIO TEST, pin T. Ground MARK, pin U. Adjust R27 (M) to obtain a counter reading of 2125 Hz. Move the ground lead from pin U to SPACE, pin M. Adjust R31 (S) to obtain a counter reading of 2295 Hz. Use a voltmeter or oscilloscope connected to AUDIO OUT, pin K, to adjust the output to a level compatible with your transmitter audio input using R32 (A). Remove the ground lead.

Phase-Locked Loop (U1)

Use a jumper to connect Audio out, pin K, to AUDIO IN, pin 18. Connect an oscilloscope or voltmeter to Hex inverter U4-8. (This voltage will swing between ground and approximately 3 volts.) Ground MARK, pin U, and adjust R3 (CF) until the Hex inverter output goes high. Remove the ground from MARK, pin U and ground SPACE, PIN M. While counting turns, adjust R3 until U4-8 just goes low. (R3 should be adjusted in a CCW direction.) Divide the number of turns by two and adjust R3 in a CW direction by that number.

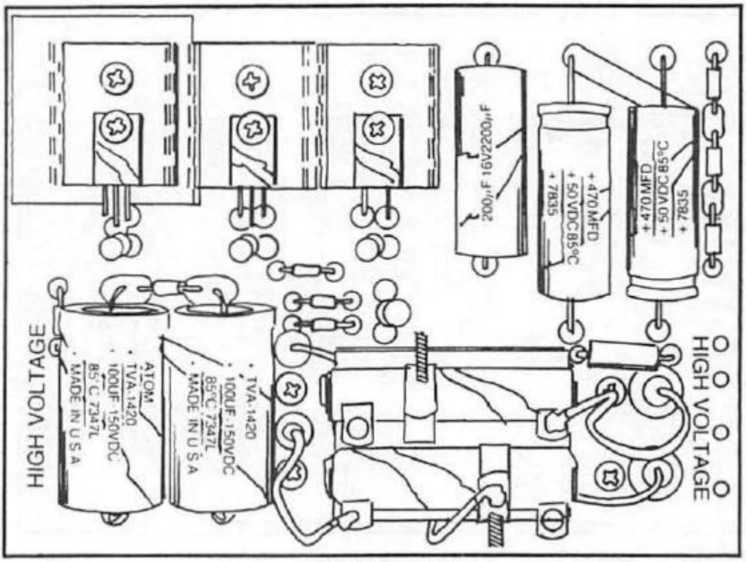


Fig. 35-4. Power supply board for the MODEM.

CW Identifier Timing

This adjustment is most easily made with the aid of another station. Initiate an Ident while the other station monitors your signal with his printer. When the timing is adjusted correctly his printer should print OOOOOOOO..... with the number of O's determined by your call sign. If you have selected the Baudot ident option, adjust the timing with R36 until the other machine prints the encoded message correctly.

POWER SUPPLY

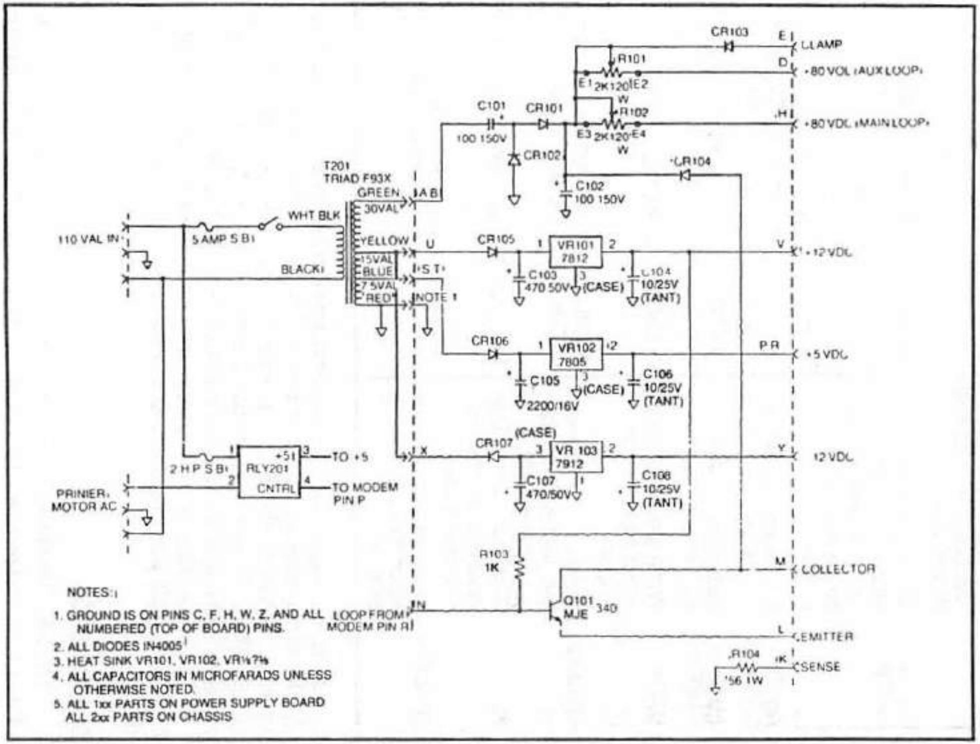
The PR-400 Power Supply was designed to furnish the voltages required by the RM-300 in addition to an auxiliary −12 VDC supply for other circuitry you may wish to add, such as a UART. Included on the board are: 2, 80 VDC, 60 mA loop supplies, +12 VDC, 100 mA, +5 VDC, 300 mA logic supply, −12 VDC, 100 mA auxiliary supply.

A high voltage loop keying transistor is also located on the RP-400 Power Supply board. A photograph of an RP-400 board is shown in Fig. 35-4 a schematic for the board is given in Fig. 35-5.

The loop supplies run from a voltage doubler consisting of C101, CR101, and CR102 before being sent to the adjustable wirewound resistors, R101 and R102.

The loop supplies run from a voltage doubler consisting of C101, CR101, and CR102. The resulting DC is filtered by C102 before being sent to the adjustable wirewound resistors, R101 and R102.

Two suggested ways of connecting your Teletype machine to the loop supplies and keying transistor are shown in Fig. 35-6. The usual connection, with the selector magnets and keyboard contacts in series, is shown in Fig. 35-6A. Resistor R104 provides a TTL-compatible low level when loop



NOTES:

1. GROUND IS ON PINS C, F, H, W, Z, AND ALL NUMBERED (TOP OF BOARD) PINS.
2. ALL DIODES IN4005
3. HEAT SINK VR101, VR102, VR⅓7⅓
4. ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE NOTED.
5. ALL 1xx PARTS ON POWER SUPPLY BOARD ALL 2xx PARTS ON CHASSIS

Fig. 35-5. Schematic diagram of the power supply board.

Table 35-2. Pin connector identification and function.

NAME/PIN NUMBER	DESCRIPTION	NAME/PIN NUMBER	DESCRIPTION
AUDIO IN/18	Audio from receiver. 680-Ohm impedance. Input level 10 mV$_{rms}$ to 3 V$_{rms}$.	+12/2, B	+12 VDC at 20 ma max.
PLL LOCK/F	TTL High when PLL locked to input signal.	+5/1, A	+5 VDC at 200 ma or less.
MOTOR/Y	When grounded causes MOTOR/P to go low.	START ID/J	Momentary ground starts CW Ident cycle.
STAND BY/X	When grounded causes MOTOR/P to go low and LOOP/R to go high (MARK level).	MSG MSB/D	Logic low for first 128 cycles of CW Ident.
AUTO OFF/V	When grounded forces Modem into receive mode without control by the PLL LOCK/F function.	MSG CONTROL /C	When grounded enables first half of CW Ident memory. When high, enables second half.
AUTO SLOW/15	0.5 Second Autostart control line.	LOOP/R	Loop control output, high for MARK and low for SPACE. Can sink 40 ma at 15 volts.
AUTO FAST/W	Instantaneous Autostart control line.	MOTOR/P	Output goes low to turn on motor. Can sink 40 ma at 15 volts.
MARK/U	When grounded forces AFSK modulator to MARK.	LOCK/S	Output goes low when PLL has locked.
KEYING/L	Normal RTTY keying line. MARK (2125 Hz) is high and SPACE (2295 HZ) is low. This input is overridden by CW Ident cycle.	AUDIO TEST/T	AFSK Oscillator test output. 5-volt p-p.
SPACE/M	When grounded forces AFSK modulator to SPACE.	AUDIO OUT/K	AFSK Modulator output, 600-Ohms, 6 v p-p max.
		CW ON/E	Output goes low during CW Ident.
		CW/N	Output goes low during each Ident key closure.

is open. If you desire separate selector magnet and keyboard connections, use the wiring diagram shown in Fig. 35-6B. Split wiring might be used when you wish to use the output of a repeater to provide local copy through a demodulator. By operating in this manner it is possible to tell instantly if you aren't making it through the repeater. See Table 35-2.

The low voltage power supplies are similar to each other in design. Each has a half wave rectifier, filter capacitor, and three terminal regulators.

CONSTRUCTION

The RM-300 Modem board, RP-400 Power Supply, solid state motor control relay and power supply fit nicely inside a 12″ × 12″ × 3″ "MOD-

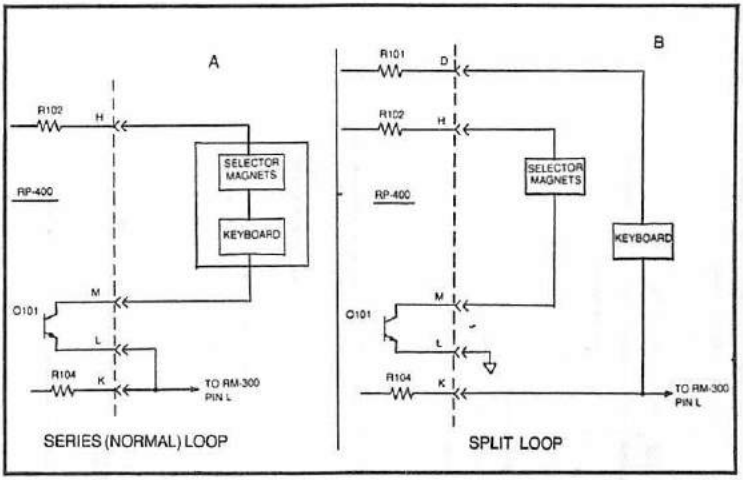


Fig. 35-6. Connections for series loop, A, and split loop, B.

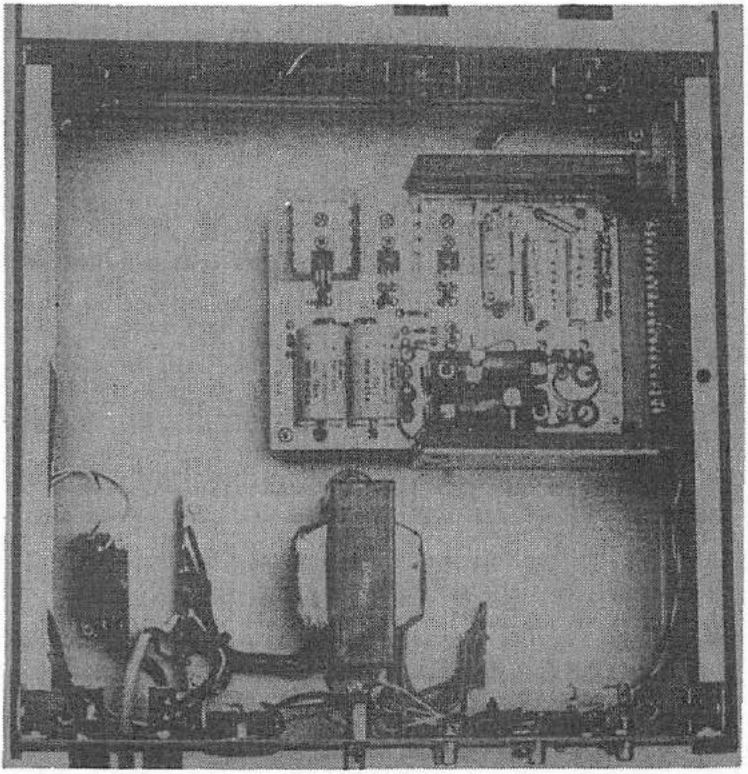


Fig. 35-7. Interior view of the RM 300 MODEM chassis.

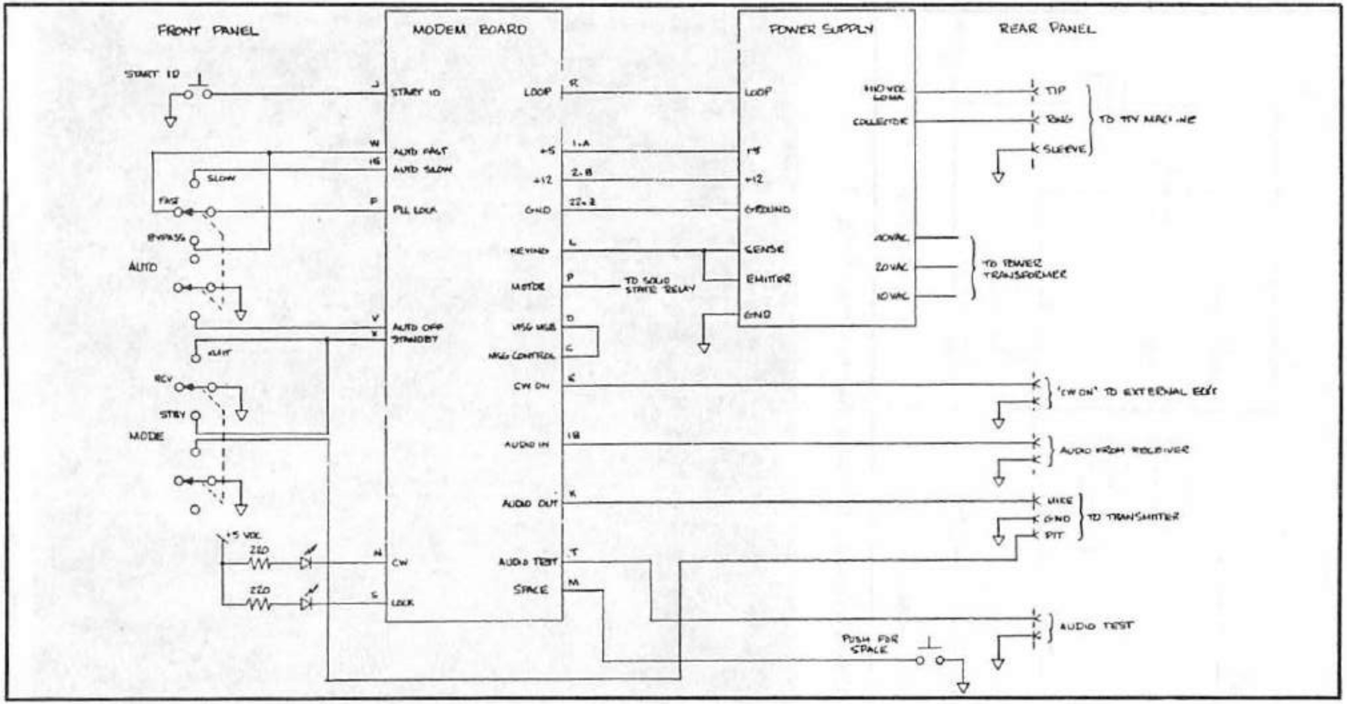
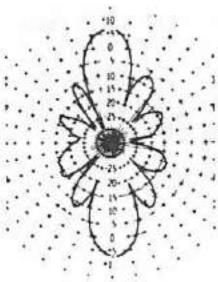


Fig. 35-8. Interconnections of the RM 300 chassis.

ULINE" enclosure. A photograph of the inside of the completed Modem is shown in Fig. 35-7.

A schematic showing one way to connnect the boards, front panel controls, and rear panel connectors is shown in Fig.35-8. Variations on this wiring will be dictated by your own station requirements.



Chapter 36
The Penultimate Systems

In this chapter I will attempt to introduce you to several of the larger Amateur repeater systems. Without exception these larger and more complicated than average systems are using converted commercial two way equipment, either on High Band (2 Meters) or UHF (450 MHz) although Amateur type equipment could be used.

This chapter is a bit difficult to write, since most system owners wish to remain anonymous. References are disguised to protect the individual system security, its owners, control stations, since they have agreed to allow the publication of this information with certain specific details left out. Two systems have agreed to let their names be published. However, please bear in mind that all of these systems are either closed or private, and would not care to be overwhelmed by a swarm of applicants. If one wishes to join a private system, it is best to be rather low key about the matter and let time take its course. It is like trying to push in a door that opens outward; the harder you push the tighter it stays shut. Just back off and let someone open it from inside. Most systems have enough users and talkers, but very few willing and capable workers. To build and keep these systems running has taken much dedication by a small handful of truly dedicated workers.

The term CTS is used to mean Continuous Tone Squelch, which is known by the trade names of Quiet Channel (RCA) and Private Line (Motorola).

Why does someone want a larger system? Perhaps it is the age-old ego trip for some: many times, it is partially because the leaders of the group are extremely sharp technical people, sometimes in the two-way radio business, who want to prove that their ideas will really work. Most of the time, a system is built to improve coverage around natural obstructions. Also, one may wish to have multiple functions which are not available in a simple system, such as, phone patch (auto-patch), emergency dialer (Police, Fire), weather or time receivers, HF or VHF remote-controlled base stations, and even remotely rotated beam antennas. Your imagination is the limit, but most of all, you need the desire to be the best in town.

Note—weather and WWV Receivers may be of questionable use; it is illegal (by some interpretations) to retransmit a non-Amateur Service.

SYSTEM A

This is a large metropolitan area with a high-band system that is currently operating with a main transmitter in a central location. The location happens to be "Intermod Alley," so a co-located receiver is totally useless as a repeater input receiver, but okay for a link receiver on UHF. Therefore they are presently (1979) using eight satellite receivers linked via UHF, with several additional sites planned for the future.

These satellite (remote) receiver sites are linked to a "hub" site via separate UHF links. At the hub a receiver voting comparator selects the best signal for use. All control functions are performed at the hub site, with the exception of CTS disable and link disable for each site. The satellite receivers are controlled from the hub via UHF control links. The sites may have the CTS disabled to permit guests to use the system if they are not equipped with a CTS encoder of the proper frequency. The only user-programmed feature is an automatic interconnect with the County Sheriff for emergency communication. All other functions, such as the selection of the backup transmitter, are controlled by the system-control stations on UHF.

The control link output on UHF permits the control stations to listen to the repeater input without transmitting on high band, and to perform other control functions without disturbing the users. A control station can also test the satellite receiver sites either on UHF only, or both high band and UHF by "rigging the election" in the receiver voter, which forces the voter to select a given receiver site. When you have more than just a few receivers (eight in this case) it is possible to have a receiver out for a few days and not miss it from the group. With eight receivers properly placed in a large metropolitan area, it is possible to have hand-held coverage over an area of close to 3000 square miles. This includes coverage from the basements of downtown buildings.

Since their goal was to have excellent hand-held coverage over the area where the work and live, the owners have certainly achieved that goal, but they are not stopping—after all, the best machine in town has to keep growing, in order to remain the top machine.

What is a Voting Comparator?

This is a device that is designed to select the receiver that has the best signal-to-noise ratio, and connect this audio to the rest of the system. A voting comparator, or voter, selects the receiver through one of several methods. The oldest method is the relay race, a DC signal derived from the receiver limiter current is placed on the interconnecting phone line, this voltage is proportional to the signal strength, and relay pick-up speed is directly proportional to the voltage. The higher the voltage the faster the relay will pick up. Therefore, the fastest relay will pick up first and lock out all the other receivers. This method has several disadvantages; the receivers had to be all the same type or the pick-up times would all be different, and, even then, with different tune-up procedures used by various technicians, there was still too much variation. The most important trouble was that once a receiver was selected, there was no "recall election" if another receiver became better than the selected one.

Later versions of voters have used multiple-tone techniques to select receivers. A voting encoder would take a sample of the signal quality with a circuit very similar to a squelch circuit, and determine if the signal was above or below certain predefined levels of quieting, such as less than 15 dB, between 15 and 25 dB, and over 25 dB. These levels would then be encoded with two tones, generally above the audio spectrum, around 2.5 to 3.5 kHz.

These tones would then be decoded at the hub site, or repeater location, and the selector would decide which signal had the best quality. This system could be set up to continuously vote during a transmission, and overcame one of the serious drawbacks of the relay-race system. However, this system still had one major drawback—it could not detect a noisy link or bad telephone line.

An even later version has overcome these problems and is designed to determine audio quality at the hub location. It does this by sampling the audio to detect the peak audio, and then detect the audio between syllables to determine the noise content. By running these two values through a logarithmic amplifier, a numerical value is derived which is proportional to the degree of quieting. This is then compared to the other receivers, and the best signal is selected. This system will take into account a noisy RF link, or a bad telephone line. However, tones on the signals, such as alternator whine and CTS distortion, will be detected as noise, and cause some confusion in the system. A good CTS filter should be installed on each receiver ahead of the voter, even if your system is carrier-operated, since some mobiles and hand-helds may have CTS for use in other systems, and cannot turn the tone off.

A good voting comparator is the heart of most major systems. The old method of changing tones to select receivers is now passé.

The link transmitters and receivers would be identical throughout the system, to maintain audio quality. If they are not, there is the chance that the audio quality will change as the voter switches. A good voter switches in 50 mS or better, and many times, the syllables of a multi-syllable word will be selected from 3 or 4 different sites—it's that fast!

SYSTEM B

This actually describes four systems which are co-located on the top floor of a downtown office building. The two high band systems are presently sharing one transmit antenna by means of a hybrid combiner and several circulator/isolators, see Fig. 36-1. There are also two UHF systems operating at the same location. These systems are operated by three different groups: one group operates both high band and UHF.

In the initial high-band operation, there was a considerable amount of intermodulation generated when operating on separate antennas. Since the introduction of the combined antenna with the additional circulators, the IM products were reduced. The addition of several circulators with separate antennas would have helped, however, the prime purpose of the antenna combiner was to reduce the site rental charge—charged by the antenna. To properly implement such a combined system, the manufacturer of the combiner system should be consulted to determine the minimum amount of isolation required for the transmitter power-output and antenna-height combination involved. A considerable amount of isolation will generally be required, 60 dB for a low power operation, and as high as 100 dB for a high-power, high-antenna combination such as this one. Since a circulator is not perfectly linear, a low-pass filter will generally be required after the

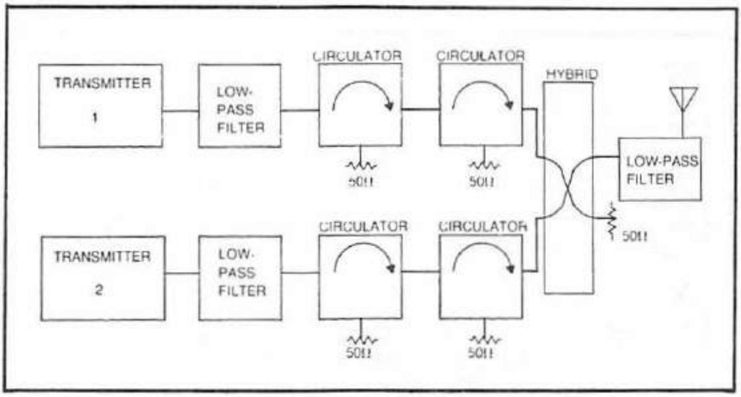


Fig. 36-1. System B, transmitters sharing an antenna.

combiner to minimize problems from intermodulation. The circulator after the hybrid may be required if there is a problem with high antenna VSWR. A 1.25:1 VSWR will reduce the isolation of the hybrid from 40 to 20 dB. That is 100 times the amount of reverse signal that you would obtain from a near perfect match. Normally, one could expect 30 to 40 dB of isolation from the hybrid, TX to TX, and 3.3 dB of loss from either TX to the antenna. The reject dummy load on the hybrid must have a low SWR and be capable of handling the power dissipation of both transmitters simultaneously, although it will normally only receive one half of each transmitter's power. A single isolater will normally provide 25 dB of isolation in the reverse direction, and an insertion loss of 0.3 to 0.5 dB in the forward direction. Again, the reject load must be of good SWR, and capable of handling full transmitter power for it's associated transmitter; in case of a combiner failure, you don't want to destroy your load and the final tube or transistor.

With the system shown, you could expect 70 to 90 dB of TX to TX isolation which is about the minimum for a high-power system from a good site. You must be sure to use a double-shielded or solid-outer-conductor coaxial cable for *all* RF interconnections—the currently available versions of RG-8, from some manufacturers, are just plain no good. They have forgotten what a shield should be like. A good single braid with 95 % coverage will give about 50 dB of isolation at 2 meters, whereas a double shield like RG9 or RG214 will give you about 110 to 120 dB of isolation. Needless to say, the "N" type of connector is preferred over the "UHF" or PL259 connector when you have a choice. A cavity can be used on the combiner output if the signals are close enough to use a ½ dB loss loop—about 100 kHz—otherwise a low-pass filter should be used.

Probably the biggest problem of running these several systems at one site was the politics between the groups. No one would ever admit to being wrong, even though there were many technical deficiencies on both sides of the fence. The constant in-fighting became rather ridiculous, and finally, one of the technical groups from the independent UHF machine was asked by the site manager to find out for him what the 2-meter groups were doing about the intermodulation problem. After much work by everybody, the IM problem was solved to the satisfaction of the whole 2-meter community.

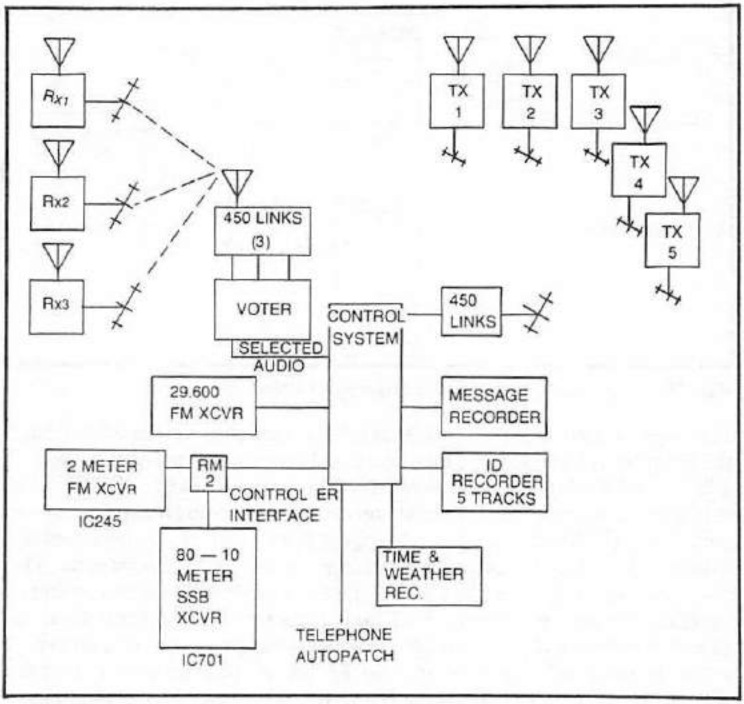


Fig. 36-2. System C, many outlying transmitters and receivers, with autopatch and remote-base capability.

Can you imagine IM products every 120 kHz up and down the whole band! Perhaps even an additional circulator in each leg of the combiner may be desired to achieve 90 to 120dB of isolation.

Remember, when sharing a radio site, if either group is in the wrong it reflects on *all Amateurs* at that and other sites, jeopardizing—in this case—four Amateur repeaters.

SYSTEM C

This system is located in Los Angeles, which is an area that is interrupted by several mountain chains. Therefore, it is impossible to cover the area with just one transmitter and receiver site. The system is the DARN—Disaster Amateur Radio Network. It operates on a high pair in the 2-meter band.

It would be desirable to operate a system like many of the wide-area commercial systems, that is, synchronized transmitters operating with precise frequency control—either with just a cycle or two difference in frequency, or precise offset of about 50 to 100 hertz difference between transmitters. The beat note is then filtered out by the CTS filter in the radio, and is too fast to cause a phase cancellation. Alas, it is not economically feasable for Amateurs to use precise frequency control, at this time, so an alternative has been chosen—user selection of transmitter sites by means of a several-digit Touchtone command. All transmitter sites are on the same UHF link frequency and the transmitters are selected by changing the CTS tone on the link, see Fig. 36-2. A multitrack, self-cueing tape playback machine—a modified broadcast "Cart" machine, is used for the verbal identification of each transmitter site. This makes operation by the users much easier; a voice is easier to read than the CW ID to find out which site in your system was last left turned on.

The receiver selection is automatic by means of a receiver voter located at the hub site, which automatically selects the best signal for use and retransmission to the five transmitter sites. This system has the additional features of autopatch (automatic, remote-controlled telephone patch), time and weather receivers (eliminates the need to call weather and time on the telephone) an 80- through 10-meter SSB transceiver (IC701) and a 2-meter FM transceiver (IC245), both fully remote controlled and a 29.6 MHz FM transceiver. Additionally, there is a prerecorded message tape which can be commanded to allow the users to hear the latest word from the owner or technical committee as to the system status, club meeting, club dinner, etc.

SYSTEM D

This system is a wide area (very wide) of interconnected "remote bases," which enables persons in one area to access a remote base in their area, or another area, by means of UHF mobiles, bases, or hand-helds. By means of a rather complicated control system, with prefix and control codes, it is a reasonably easy system to operate when one understands the way the equipment works, but can be a disaster to the uninitiated operator, creating lockups and other problems.

When operating the remote from the local UHF channel you enter a prefix and then a function code. When operating from the UHF link access via the switching center or another port on the system, an access code is required, and then a dial-tone is received, at which time you enter the appropriate function. When the function has been completed, a function-

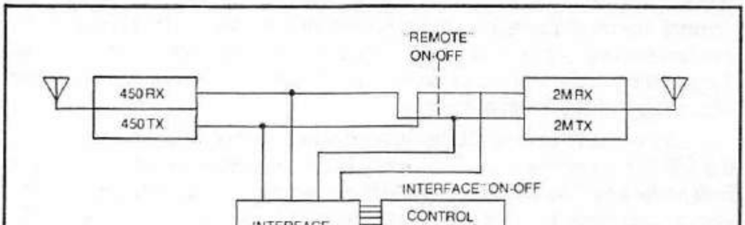


Fig. 36-3. One of many sites typical of System D.

complete beep-tone is transmitted back to the originating station. The function codes are essentially identical at various locations in the system so that one does not have to carry a book full of codes to remember how to use the system. Although each site is operated by separate groups, this is an excellent example of cooperation toward a common goal. Figure 36-3 shows one of many typical sites in the system.

The system can be thought of as in a star configuration, with several of the arms extended by additional links, see Fig. 36-4. Some ports on the system are accessed via the switching center, while others are connected directly into the "backbone" of the system. Due to the way the access codes and operation of the system works, this does not create any severe operational problems.

Since it is possible to interrupt the backbone link of the system at any point, it is possible to have sites W1 and N1 connected via the switching center while W2 and W3 are handling a separate conversation, and N2, N3, N4, N4W, and N4E are doing their own thing; perhaps a mobile at N3 talking with a hand-held at N4E, with N2, N4 and N4W just listening in, although N4 could drop off and not disturb the conversation. It is possible for a mobile at N3 to access a 2-meter remote at N4E on 146.520 MHz, and talk to a 2-meter station just as if he were using his own base station—except with much improved coverage. Since it is possible for an operator to link through a location without "dumping" on two meters or the local UHF channel, the local operation is fully bypassed and may operate its 2-meter remote independently of the system. Of course, while I say 2-meter remote operation, it may just as well be 6 or 10 meters.

With this configuration of 2-meter remotes, it is possible to monitor a channel without transmitting, while holding a conversation on UHF. Since many of the mobiles and base stations have full duplex capability—receiving the output of the machine while you are transmitting—the monitor function is very valuable. Two modes can be selected, monitor mix and monitor mute. The monitor-mix mode provides audio from 2 meters at normal volume, while the monitor mute provides a muted level from 2 meters, which is reduced by a controlled amount of approximately 10 to 20 dB. Also, it is very desirable to have a set of timers which will reset the remote to a normal status if there has been no activity on the UHF channel for a predetermined amount of time. This is very useful should an operator forget to reset the system or drive out of range, or, Heaven-forbid, in case of a failure of the control system.

One of the interesting items to note is their use of a 1064 hertz tone for the CW ID generators, this frequency is the geometric mean of the upper limit of the low Touchtone group and the lower limit of the high Touch-Tone group, therefore this tone is filtered out and does not bother any subsequent tone decoders in the system. Also, it is a low-distortion sine wave, never a square wave. Additionally, there are telemetry tones on the system which are sent back to the operator to indicate system status, such as remote on, interface on, link on, and 22-meter transmit—these combined with the system dial-tone, busy-tones, function-complete tones, and invalid-function tones make for fairly straight-forward operation very similar to the old days of manual long-distance telephone-call routing by the operator.

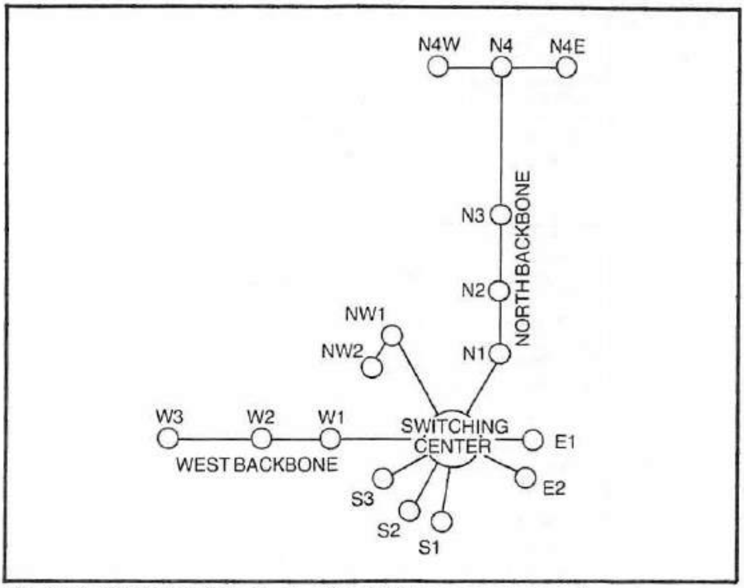


Fig. 36-4. Overall system D, showing backbone arrangement.

The next step down the line is microprocessor control. It's not too far away, I've already seen the boards.

SYSTEM E

System E is a group of UHF-controlled, 2-meter remote bases in the greater Los Angeles area which are operated by independent groups under the auspices of one operation. Each system is run by a "benevolent dictator," since this has been found to be better than a club for this type of operation.

These operations have started independently, but after several years have drifted toward a common goal. They are somewhat similar to system D, described earlier. At this time, the outlying portions of the system are in operation as UHF-controlled remotes, and the switching center in Burbank, California is under construction. It will take several years to complete the microwave system (10-GHz Gunn-diode oscillators) as well as all of the functions and controls.

System E in Fig. 36-5, at this writing, is an operational UHF remote, as are systems F, K1, K2, and B. However, the interconnection of the switching center will permit several functions to be shared among systems. All sites can access the Burbank Switching Center (BSC) with a partial sharing arrangement. Only one site may access the transmit command for a given function (such as 146.52 FM), while any site may access the receive or monitor functions simultaneously (more than one can listen while another transmits). If one tries to access a transmit function while another has it, all but the first one will receive a short burst of a busy signal, and then will be shifted over to the monitor function instead.

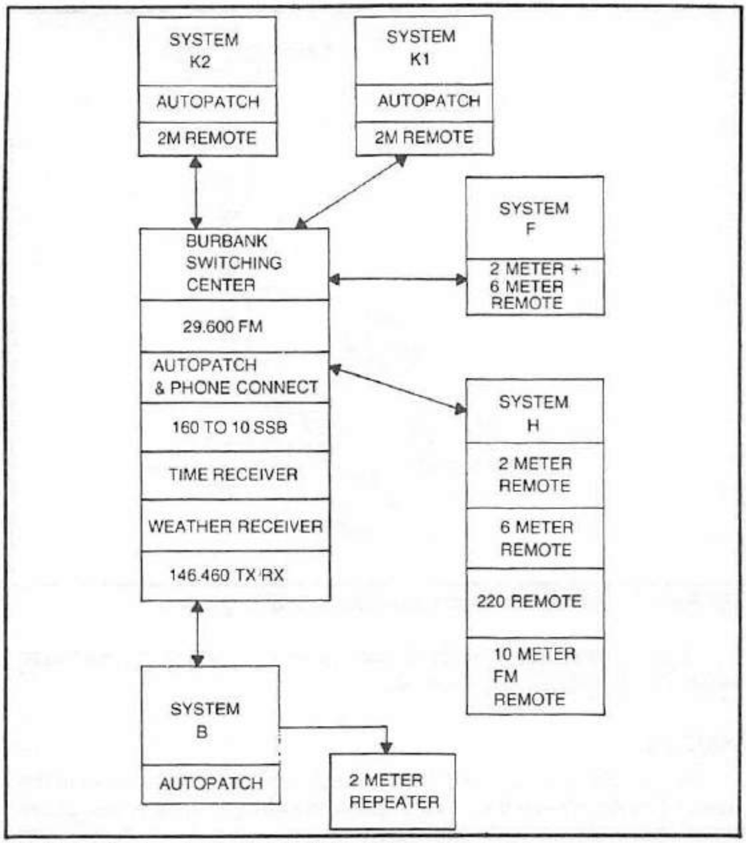


Fig. 36-5. System E, the SOBER Radio Empire system.

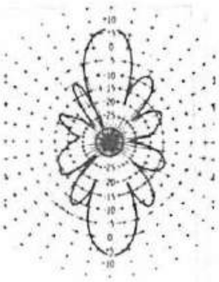
Normally, one will access the monitor function before the transmit function is entered, at which time they will receive a short burst of an in-use tone, which indicates that the function is in use by another person. This will prevent the changing of a function, which could be an inconvenience for the original user. Obviously, there is no need for a busy tone on a monitor-only function, such as the time or weather circuits.

It is planned to have multiple access to each site (more than one link), so that one system may access another site's functions. For example, a user on system F can access the 220 remote on system H, while a user on system B can access the 6-meter remote, and system H is operating its own 2-meter remote—all simultaneously—and systems K1 and K2 are unaffected.

Perhaps some of the points common to all of the systems described are: 1) private or closed systems, 2) commercial quality equipment, 3) excellent technical staff, 4) almost no incompetent operators, 5) tight-knit club or dictatorship, 6) excellent control operators—especially system A, 7) a goal to be the best system in town, and 8) DEDICATION!

Chapter 37

The Simplex Autopatch



Having had a desire to build a small and portable autopatch system, an approach was conceived and implemented that might be of interest to other amateurs. This approach is called the Simplex Autopatch.

Note that I say conceived, and not invented, for the Simplex Autopatch has been invented and re-invented many times in the past, yet has not achieved any great degree of acceptance.

In principle, the Simplex Autopatch is a very simple device. It is small, inexpensive to build, and portable, which has a distinct advantage, such as providing portable emergency autopatch communication services with a minimum of hook-up effort. It does not require cavity duplexers but, instead, operates on a time-share basis, and transmits and receives on the same frequency. Another advantage is that the system is unable to interfere with another station operating on the same frequency since, if an incoming signal is present, the transmitter is held disabled.

It should be noted that a Simplex Autopatch is neither a repeater or a remote base and, as a matter of fact, is a separate mode of operation which has a relatively low duty-cycle.

Simplex Autopatching is accomplished by causing a control circuit, while in the autopatch mode, to turn off the transmitter for a small time period—such as 1 millisecond—and activating the receiver for this time period to see if a signal is present. If the receiver senses a signal, the logic is such that the transmitter is inhibited from turning back on until the signal disappears, or, seeing no signal, allows the transmitter to turn on for another time period. Representative times are: XMTR ON, Second; XMTR OFF, 0.001 seconds . The XMTR-OFF-time is called the receive window.

So, in operation, the events occur as shown in Fig. 37-1. All that is necessary to accomplish this is a small logic board which contains the control circuit, tone decoders, and a timer, plus some minor modifications to the transceiver. The system shown here uses an IC-22A, but the principle can be applied with equal ease to any of a variety of transceivers.

In operation, rather than switch the receiver on during each 1 mS receive window, and get involved with more of the time constants encountered when switching a receiver on and off, it was found that it is much better to let the receiver remain on during the transmit period and, through the logic, to "don't care" that the receiver is hearing the transmitted signal. This has no detrimental effect on the receiver, and avoids the time con-

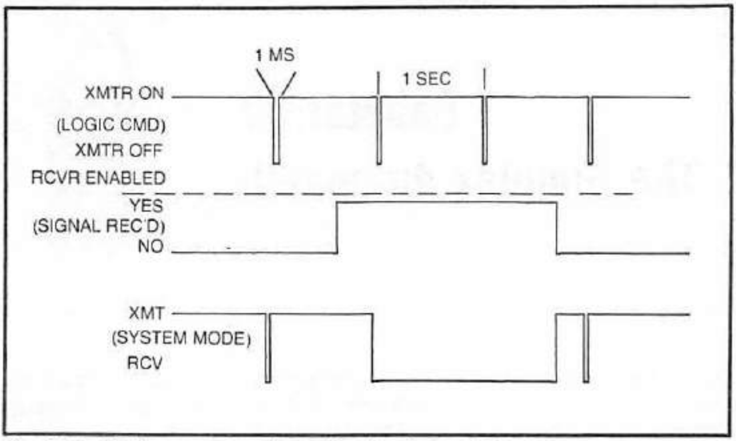


Fig. 37-1. Timing sequence for a Simplex Autopatch system.

stants that would be present when switching the B plus (or +Vcc if you prefer).

Another important change to the transceiver is to modify the receiver squelch time-constant. In order for the receiver to respond to a signal present during the 1 mS receive window, it must have a time constant shorter than this period. Most FM receivers, as built, have time constants in the order of 30 to 50 milliseconds. This change is easily made by changing one capacitor in the receiver squelch circuit. This practically eliminates the squelch tail, and might be of interest to those not building a system such as this.

If this change is not made, then, when the transmitter turns off, the squelch will imagine it is receiving a signal because of its time constant, caused by the signal previously heard (its own) while the transmitter was on. This can cause a quite audible interruption in the transmission. However, by shortening this time constant, the interruption sounds like and extremely short tick, and is almost unnoticeable.

CIRCUIT DESCRIPTION

As shown in the schematic diagram, Fig. 37-2, receiver audio is brought into the control logic on pin 6 of a double-sided, 22-pin connector board. Any number of boards can be used for this circuit.

The receiver audio is routed to the 567 tone-decoder chips set up for standard Touchtone frequencies. For example, if you wish * on and # off, then G5 is tuned to 1209 Hz, G6 to 1477 Hz, and G7 to 941 Hz. The receiver audio is also sent to a level-control, R1, through relay K1, and transformer coupled to the phone line.

Upon application of * (941 hz & 1209 hz.), G7-8 and G5-8 both go low causing G4-1 to go high. Upon release of the G4-1 goes low and is negative-edge-coupled to the set-input of R-S flip-flop G3-1.

At this point I should note that the reason for setting this flip-flop on the negative edge is so that the telephone line will not be connected until the tone is released. If not done this way, the access tone(*) will be recognized by the phone company as the first digit of the number you wish to dial when connected, and may or may not cause problems, depending on the individual telephone company and its equipment.

At any rate, G3-3 is set high, thereby enabling G2-3 in the pulse mode. G2-3, when high, allows the pulses from timer G8 to be processed through and key the transmitter on and off as described previously. Timer G8 is an astable 555 timer set for 1 second on and 1 mS off.

G2 also is the determining circuit to disable the transmitter if an input signal is received. This occurs as follows.

During an XMT period, G2-6 and G2-2 are low, thereby forcing G2-12 high and forcing G2-1 to ignore any receive-signal sense. This is done so the logic won't recognize the fact that the RCVR is still on, and receiving the

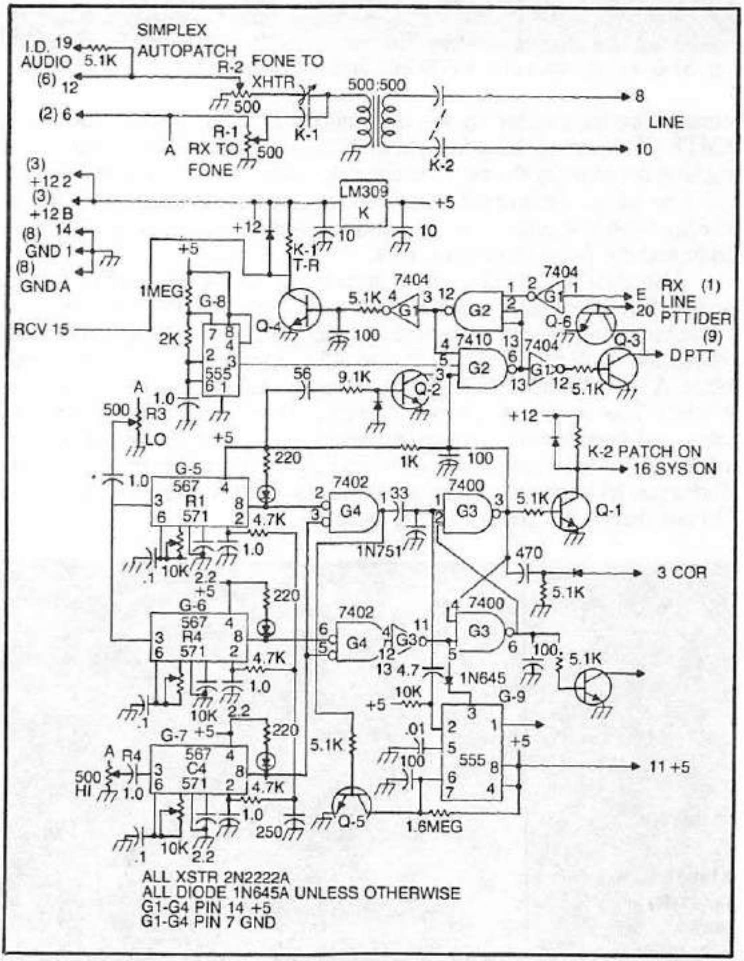


Fig. 37-2. Schematic diagram of timing generator and logic circuitry for the Simplex Autopatch.

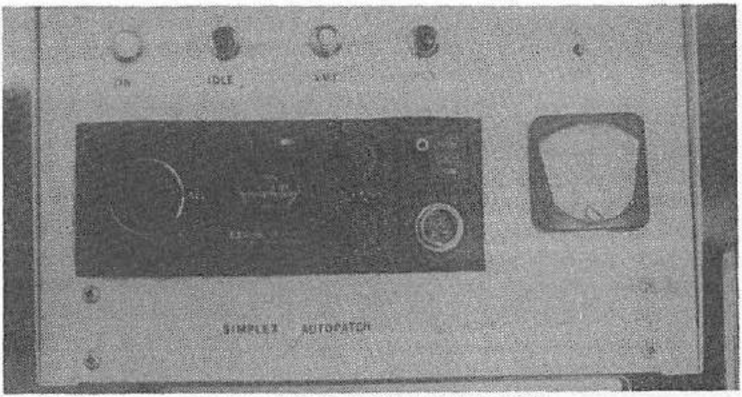


Fig. 37-3. Front panel of the W2MNN Simplex Autopatch.

signal being transmitted by the transmitter. However, during the 1 mS XMTR OFF period, G2-2 is high, and that section of G2 is enabled. If a signal is detected by the receiver squelch circuit, input pin E goes low and G2-1 goes high, making G2-12 go low. This interrupts the pulse mode by making G2-4 low until the received signal disappears, allowing G2-4 to go high, and the pulse mode continues.

Also attached to G2-12 is an inverter G1 and a relay driver Q4, to accomplish phone-line switching between transmit and receive. The capacitor is to prevent phone-line switching and the accompanying ticks during the 1 mS receive window, and yet allow smooth switching to take place. Also, at the same time of tone release of the access code, timer G9 is started. This is the patch time-out timer, set for approximately 180 seconds, and if you run out of range or otherwise lose control of the autopatch, will turn if off upon completion of its timing period. The timer is resettable during patch operation by punching the access code(*), which also turns on Q5 and dumps the 100 μF timing capacitor.

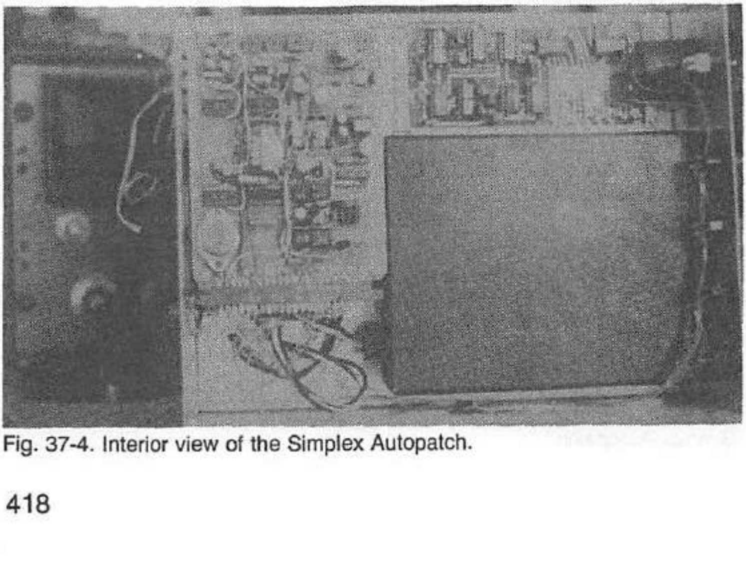


Fig. 37-4. Interior view of the Simplex Autopatch.

The front panel of the Simplex Autopatch is shown in Fig. 37-3. The interior is shown in Fig. 37-4..

So much for turning the system on, How do you turn it off?

If # is the off code, then decoders G6-8 and G7-8 will go low upon receipt of a #, G4-4 goes high, G3-11 goes low, thereby resetting R-S flip-flop G3. Other connections shown are:

Card pin 3 COR to start IDer
Card pin 7 XMT ON command from IDer.
Card pin 19 IDER audio.

A VHF Engineering IDer was used in this system.

All power for the control logic is derived from the 9-pin connector on the IC-22A, and is the only connection required.

Typical connections to the IC-22A are shown below:

FROM	TO	FUNCTION
IC-22A-6	P1-12	Phone to XMTR audio
IC-22A-2	P1-6	RCVR to phone audio
IC-22A-3	P1-2	+12 VDC
IC-22A-3	P1-B	+12 VDC (for current capability)
IC-22A-8	P1-1	GND
IC-22A-8	P1-A	GND (for current capability)
IC-22A-7	P1-E	RCVR Sense (low for signal rcvd)
IC-22A-9	P1-D	PTT (low for transmit)
IC-22A-1	A Disc. Mtr.	Approximately 10 μ A/kHz

SIGNAL NAME	PIN	FUNCTION
IDER Audio	19	I.D. Audio
IDER GND	1	GND
RCV Lamp	15	Low when in RCV mode.
Line	8	Phone
Line	10	Phone
SYS ON LAmp	16	Low when SYS ON
IDER COR	3	Low going starts IDer
IDLE Lamp	13	Low when SYS in IDLE.
IDER + 5 VDC	11	+ 5 VDC to IDer
IDER PTT	20	ID ON (Transmit command from IDer)

The indicator lights are wired as in Fig. 37-5.

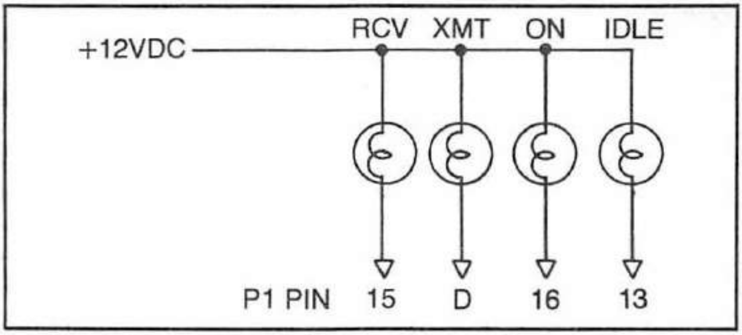


Fig. 37-5. Indicator-light wiring diagram.

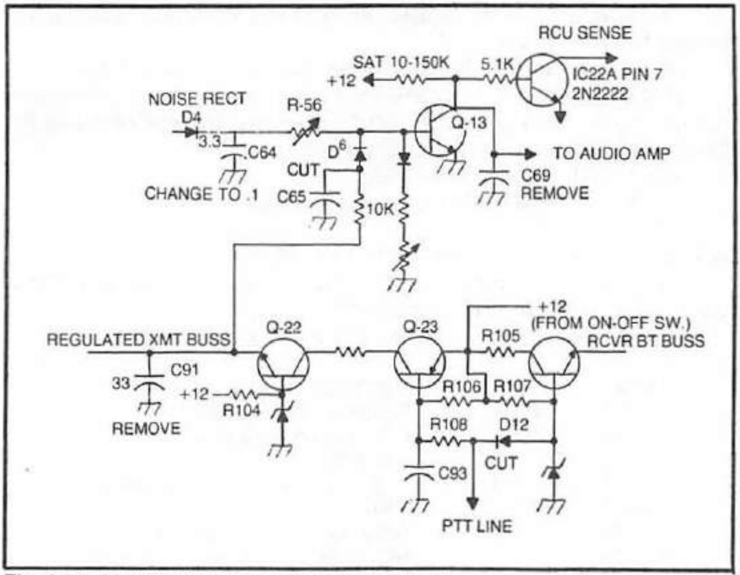


Fig. 37-6. Modifications to an IC22 transceiver.

TRANSCEIVER MODIFICATIONS

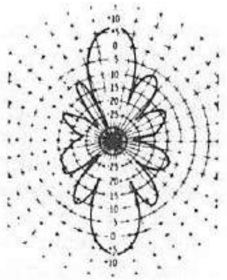
Now for the easy part. The examples shown in Fig. 37-6 are for an IC-22A, but can be applied to almost any transceiver. However, the transceiver should have solid-state antenna switching to be effective.

Make the following changes:

- Cut cathode side of D-12
- Remove C-69
- Remove C-91
- Change C-64 to 0.1 μF.
- Cut anode side of D-6
- Add a transistor to buffer the squelch as shown.

It is hoped that the description and illustrations presented here will enable the reader to build a working and effective Simplex Autopatch System.

Chapter 38
The Linear Translator



Thus far, we have discussed only Amateur relay devices operating in the FM mode. How about other modes? CW, SSB, FAX? Can they also be relayed as is accomplished with FM voice? The answer is yes. In the case of SSB the system used is fascinating. It is called Linear Translation. This is not a new concept; many remote areas obtain both FM Radio and Television Broadcasts through linear translators.

A REPEATER VERSUS A LINEAR TRANSLATOR

Let's compare an FM repeater and a linear translator to see how they differ. An FM repeater is a device that looks at a specific frequency, and a signal appearing on that particular channel is amplified, detected, and the recovered audio modulates another transmitter. In a linear translator, no detection takes place. The translator's receiver looks at a specific bandwidth rather than a specific frequency. Any signals appearing on the input are converted to an intermediate frequency, where they are amplified in linear fashion by Class A amplifiers, and then again converted to a new frequency, where they are further amplified and retransmitted. Since, in practical Amateur application, the translator may be simultaneously retransmitting a number of signals, the output power is equally divided between the total number of signal.

For instance, suppose we are owners of a 100-watt output SSB linear translator. This means that, with one signal present at the receiver, it will retransmit that specific signal at a power level of 100 watts. Suppose two more signals appear in the receive window. They are each on discrete frequencies, however, as long as they are in that "window," the translator will retransmit each. Now, the transmitter is handling three signals, and therefore can only produce 33.333 watts output for each one. If 100 users jammed themselves into the receiver's window, each would be retransmitted at a level of 1 watt.

Note that we use the term "discrete" in relation to signals. This is because the translator, in theory, has the ability to handle an unlimited number of discrete signals at any given time. However, there are certain practical limits to translator type of operation. First, there is division of transmit power. Too many stations trying to use a translator at the same time can reduce its output power to a level where its operation is not worthwhile. Again, to our analogy of a 100 watt translator with 100 users, each getting "1 watt" off the hilltop. One watt from a high location can do wonders. On SSB it can cover hundreds of miles, as shown by the OSCAR series of Amateur satellites. However, what if 1,000 Amateurs tried to use a translator at any given moment? Each might get into the system, but his effective output would drop to 0.1 watt. Not a very effective power level for any serious DX work, though still with possibilities. Actually, for a 100-watt mountaintop translator, about four to six users at any given instant is a logical number. This would give each of the six a worst case output of 16.666 watts; an adequate figure for good DXing.

There is another drawback to our theoretically unlimited number of users. A translator looks at a given window. If it were to operate on two meters, the maximum it could safely look at without causing interference to other spectrum users might be in the neighborhood of 12 kHz. Since the average SSB signal is 2.5 to 3 kHz wide, and allowing for zero guard band between four QSOs, we obtain a theoretical maximum of four users at any one time. This theoretical maximum is also a practical maximum.

So far, we have made an assumption that all stations accessing a translator will be reaching the receiver with the same signal level. Again, theory is nice, but in the real world, theory does not always apply. In practice, a stronger signal entering the translator will produce a higher output level from the transmitter. Therefore, a station five miles from the translator, with an ERP of 100 watts, will produce a proportionately higher output level than a station running 10 watts at the same distance. Of course, high-speed AGC circuits could be employed to counteract this problem. However, the problem here is that overall system sensitivity will be reduced in order to "level" the high-power stations, thereby making it more difficult for weaker stations to access the system. The obvious solution is to request that stations using such a system utilize the minimal amount of power necessary. Unfortunately, this does not always work, since it is impossible to control the operating habits of each amateur.

OPERATION

Thus far we have looked at the practical operation of such a device without discussing its normal operational procedure. As of today, most amateur translator activity has centered around the OSCAR transponders, which are cross-band devices. That means a signal going in on one band—say 2 meters—appears cross-band with an output on 10 meters. In a like manner, television translators serving sparsely inhabited areas will "look" at a specific VHF channel, and convert or "translate" it to a UHF channel. Note that in both broadcast television and Amateur relay operation, we are looking at cross-band operation. Is it possible to make such a device operate in-band—say on 2 meters, using a normal 600-kHz input-to-output separation so as to integrate such operation into existing 2-meter repeater activity? Experts on the subject say that they believe such is both possible and probable. However, there is a key to the success of such a system, which comes in the form of a receiver characteristic known as dynamic range. We covered the subject of dynamic range earlier, and said it was the ability of a receiver to properly process or handle a weaker signal, while other, stronger signals were within the same front-end passband. Here though, we are not looking to "reject" a particular signal. Rather, a translator receiver must have the ability to properly process all signals appearing in its passband. A minimum dynamic range figure of 120 dB is necessary for an in-band mountaintop linear translator. Can such a figure be obtained? Thanks to recent advances in linear solid-state technology, receivers with a dynamic range figure of over 100 dB have been developed. However, you won't find them in your favorite ham-radio equipment supplier or surplus equipment palace. They have been designed for industry and government, and it will be many moons before Amateurs get their hands on them. For this reason, there are no "packaged translators" available as there are "packaged repeaters." Nor will you see "SSB translator kits" in the very near future. This is one case where you must do your own design research and development. A translator is a very intricate device that requires a working knowlege of advanced receiver design.

There is another translator characteristic that we must speak of. To a person who builds and places into operation an FM repeater, there is a certain ego satisfaction each time the system comes to life. The sound of the repeater's carrier, the callsign on the ID, and whatever else, is an indicator to the world that "this repeater belongs to me." There is no such ego satisfaction in translator operation. There is no "whomping carrier" coming of the hilltop; no discernible ID. Most translator experts feel that 50 to 100 Hz FSK is the ideal method to ID such a system. Therefore, relatively speaking, translators have little ego appeal. Listening across their output passband will seem like listening anywhere else; just individual signals and QSOs, with no readily discernible indication that these signals are being relayed. Probably few, if any, that use such a system will have an idea who placed it into operation—nor will they care. On a repeater, every user knows who the system owner or licensee is. To someone on an ego trip, someone looking for public recognition, the linear translator is a real bummer. To the true experiementer, the person who cares little for public recognition, the translator is where the future lies.

Operation through a translator will probably more closely resemble low-band HF operation than VHF relay operation. Assuming that translators will utilize the normal 600 kHz input-to-output separation on 2 meters, one will simply listen for a clear spot in the output passband and transmit exactly 600 kHz higher or lower. Nor will most operation be channelized. In looking for a QSO, you will "tune" the same way you tune to locate a station you wish to QSO on the 40 or 20 meter bands. Actually, there will be no way for you to know that you are operating through a relay device without some provision for detection of the system ID. You will gain the freedom of VFO operation with the additional range afforded by relay communication. Another bonus will be not having to wait for one QSO to end before beginning your own.

With so many open FM repeaters in operation, why go to SSB relay techniques? There are many reasons. First, our spectrum, expecially on 2 meters , is growing more crowded each day. Eventually, there will come a time where there is no longer room for more repeaters and more users. There are certain laws of physics that state only a specific number of entities will fit into a given space, be it apples in a box or repeaters on 2 meters. The outcome is the same. A linear translator with a 12-kHz receive window gives you a 4 for 1 tradeoff, and with modulation-folding techniques, the total number of possible users can be increased even further.

While translators can and will function as DX monitors, I do not forsee this as their prime purpose. I suspect their major utilization will come in the form of local or extended range "gab-channels" in the same way that repeaters serve us today. Though I feel most Amateurs will prefer the freedom of VFO control, some channelization for nets or "in" meeting-spots would not surprise me.

Another translator concept that might develop is the "Remote-Base Translator" which operates in a manner similar to an FM or FM/Cross-Mode remote. Such a system, with linked receivers/transmitters on 50.110 SSB would be the ultimate in 6-meter DX monitoring. Even better, if the 6-meter portion of the system were "passband" as well, making it possible to "tune" 50.0 to 50.35 MHz for example. The overall possibilities are limitless.

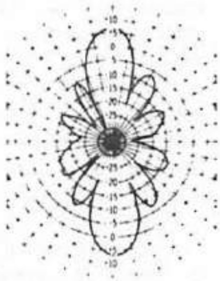
Coordination of translators is a far simpler job than repeater coordination. You are dealing with overall spectrum rather than with specific frequencies. If two translators decided to cover the same exact geographic area, which is highly unlikely, the result would probably go unnoticed so long as both systems translated with the same accuracy. Should such a problem arise, it would be the Amateur community that would make the loudest noises to solve it! In practice, some overlap between translator systems would be welcome, whereas in repeater operation such is rarely wanted. Again, if interference were to develop, you just take your QSO "up or down 5."

Translators are low-environmental-impact devices. They do not displace any existing activity as repeaters do, and operate as an "adjunct to" rather than as a "replacement for" any activity. This is because the translator has the ability to relay virtually any mode. True, its future lies with SSB, but this does not preclude repeating AM, FM, RTTY, FAX, or whatever. The translator could care less—what ever it sees, it relays. However, the real advantage of the translator is when it is used with narrow-bandwidth techniques, thereby affording a high level of spectral conservation. The experts contend that, on 2 meters, user capacity could be multiplied four times if linear translators, along with narrow-band user techniques, were to replace the current trend toward FM and FM repeaters. There would be a number of drawbacks, especially in regard to noise, since SSB is a form of AM with the same pitfalls that AM has. However, most agree that the in-band linear translator has so much going for it that it is the obvious next generation relay device.

Only time will tell! As this is being written, there is already one fully operational FM translator in California's High Desert, and at least three known SSB units in development throughout the state. The concept has been proven workable enough that many coordinators and coordination councils, as well as the ARRL, have reserved space for such operations in the various bandplans. In Southern California, for example, 144.52 and 144.54 MHz, along with their respective output pairs, are for non-FM relay devices only. Other areas have taken similar action. Still others have cluttered the new 2-meter spectrum with FM repeaters, without any thought to the future. Those will be the places where problems arise.

The linear translator will not replace FM repeaters overnight. Repeater and FM operation are very well established and will be here for many years to come. However, you can expect that future developments in non-FM weak-signal relay devices to come of age over the next ten years. Some in California will probably be operational long before this book reaches print. The technology of today and tomorrow has made this possible.

Chapter 39
Repeater Owner's Guidelines



When an amateur takes on the task of repeater system operation, he also assumes certain obligations. Some of these are direct—he must get the system going. This means design, installation, implementation, and debugging. Once all this has been accomplished there is maintenance. The amount of time he must devote to this will be directly dependent upon the initial quality of the equipment, and the care with which the system has been built. A good rule of thumb is that the later the vintage of the basic hardware, the less time that will be spent keeping it operational, assuming that it is all of good quality.

STAYING ON THE AIR

Keeping the system operational at all times is very important, especially in regard to open FM repeaters. Amateurs in any area come to depend on such devices and, after a while, they are taken for granted—almost as if they came with the band or were an integral part of the user's radio. When a repeater malfunctions it can have an almost catastrophic effect on its usership. Let me relate one experience in that regard.

Over the years, I have either owned outright, or held license for, a number of amateur repeaters—open systems for the most part. One day a few years ago, I was at the site of one system to perform some routine maintenance and announced via the local microphone that the repeater would be "down" for an hour or two. It was midday, and the channel was quiet. Hearing no response, I turned off the transmitter power supply, since the work to be performed was in that portion of the system. The receiver was left turned on, and the local speaker volume was turned up. A short time later, the receiver came to life and I heard a normal call from one amateur trying to contact another. When he received no answer or squelch crash, he proceeded with the question: "Is something wrong with my radio?" Still getting no response, he came on the air once more rather obviously tapped is microphone against a hard surface, as if this act would be the "magic" to restore things to normal! The tapping was followed by a question: "Doesn't anyone hear me? This is standing xxxxx by." Needless to say, my attention was drawn away from my work, toward the commentary emanating from the speaker. The operator seemed very upset. The desperation in his voice, coupled with his attempts to remedy his dilemma by brute force applied to the microphone, finally was a bit more than I could handle. I had with me a portable unit equipped for both input and output-channel simplex, and, utilizing this rigid contacted the gentleman to explain what was happening. I honestly thought he would be pleased to know that we cared enough about the system to provide regular maintenance. I was not expecting the response he gave. It was something to the effect that he and others would not tolerate the inconvenience of the system being off when he wanted to use it, and if we wanted to work on it, such work should be done only in the wee hours of the morning when nobody would be using it. Was I ever caught off guard!

My first reaction was to tell him where to go, and what methods to use to reach his destination. However, I valued my amateur license more than the need for retribution in kind, so simply ignored what I considered unwarranted commentary, and continued with my work. After a few more invectives he disappeared when he found nobody paying him any heed. About a half hour later, there was almost a replay of this drama. Another user showed up and placed a call. He, however, realized that the repeater was off the air and his next transmission was obviously directed at the system hardware itself. His tone was sullen and condescending as he accused the repeater of breaking down just when he wanted to use it. He spoke as though he felt the hardware could and would understand his displeasure with the situation, and when he was through, I was almost tempted to answer him with two words; "I understand." Obviously doing so in a way that would let him think the system itself had provided comfort in his hour of need. No, I didn't. Instead, I thought to myself, "Is any of this for real, or will I wake up in a few minutes to find it all a nightmare?" As the afternoon wore on, others came by, noted the system was inoperative and spent a few moments chastising it and those running it. Suddenly I realized something that had escaped me. Though it was an inanimate object, the repeater actually was a life form of its own. In the past, it had kept its promise to extend communication range, and was complimented for its efforts. Now it was as if that promise had been broken, and those who felt their "friend" had let them down were offering what they felt was due criticism. I stepped back for a moment and stared at the conglomeration of electronic circuitry and wondered if I had helped create some for of monster. It was inanimate, yet those who used it had given it life!

If you think this is an isolated occurence, let me tell you what happened to a friend of mine in a city far removed from my experience. This particular person was part owner of a very popular, open, two-meter machine, and one night it failed. He became aware of the failure at about 3 A.M. when his ringing telephone woke his entire family from a rather sound sleep. Bleary eyed, he answered and found a rather irate voice on the other end of the line, demanding in no uncertain terms that he immediately take his body to the site and repair whatever ills the repeater was suffering. Figuring it to be a crank call, he hung up after telling the guy off, and headed to bed. He did not get very far. The phone rang again, and this time it was someone else making the same demand. Disturbed, he simply told the caller to hold on, and then disappeared back to the land of nod—leaving the caller holding the bag. In the morning he had the phone company change his number to an unlisted one. He was so distrubed over what had happened that he put off repairing the system for several weeks, and shortly thereafter sold it to someone else. As he said to me one evening on the phone, "Who needs the headache?"

Over the years, I have heard many stories such as this, from repeater owners all over the country. Had I not experienced it myself I would not have believed it could happen. It does, and I think that the reason is quite simple. As stated before, users come to think of a repeater as a friend who will always be there to help. Through ice, snow, and dark of night, this friend is always there to provide comfort and entertainment. In time, its inanimate status is forgotten, and the "machine" takes on a reality of its own. Therefore, can you really blame the user for his actions when his "friend" is not there to serve him? I think not. This is nothing more than a natural human reaction to being hurt or put upon in a way he feels is unfair. The successful system owner is one who recognizes and accepts this part of human behavior as being natural, and does not try to alter it. He must not consider it to be personal criticism of himself or his abilities, but rather the normal venting of anger on the part of normal human beings.

TIGHT QUARTERS

Channels are not sacred, especially within the two-meter repeater sub-bands. In some areas, activity is at such a high level that every channel is used by more than one repeater. For some, co-channeling has become a way of life, while to others it will be a new experience when activity hits a level which requires such sharing. Eventually, it will be the rule of the day in most places, if current growth patterns persist. When the time comes that you as a repeater-owner/operator are faced with sharing your channel pair with others, how will you react? Will you accept it as the cost of progress, or will you elect to fight it with a vindictive attitude which says "me first?" The fact is that those hurt the most by a repeater war are the users, and they should not even be a part of the problem in the first place. It has been proven that such acts are naught but a waste of time. One cannot impede progress to satisfy one's ego, and the truly successful repeater-owner/operator is an individual unafraid of tomorrow, and of a personality makeup that permits him to adapt to any situation.

A system owner has responsibility directly to the community. We live in an age where any kid with ten dollars in his pocket can run down to the local discount house and procure a radio with some capability of listening to the VHF/High public-service band. Admittedly, such receivers lack many frills. Nevertheless most of these $10 wonders have the ability to hear local, two-meter activity, and a strong signal from a local repeater is bound to attract attention. The impression these outsiders get of your system will be the public image of all Amateur activity in your area. Therefore, it is up to you to make sure that those who use your relay facilities operate in a manner which shows respect for all who may be listening.

This is not to say that you should become a "radio cop," sitting at the ready 24 hours a day so as to censor what you may disapprove of. To do so would accomplish little other than angering the masses to a point where they would try to see how far you could be pushed before "throwing the big switch." It does, however, indicate that you cannot be aloof from those who use your repeater. You must get to know them, and they must get to know you—perhaps through regularly scheduled meetings. There, you can exchange ideas and learn each other's likes and dislikes; you can become more attuned to each other. You are looking for their support so that, if something unforeseen should happen, such as willfull and malicious jamming of the system, any action you are forced to take will be indicative of their feelings as well.

HANDLING INTERFERENCE

Speaking about willfull and malicious interference, what action should you take if it occurs? I'm not speaking about the once-in-a-while "autokerchunker." Eventually his finger will tire, or perhaps fall off, and he will go away. I speak of the foul-mouthed individual who never seems to disappear. The sickie who is there night and day with any obscene utterance which strikes his fancy. Here, you are caught between a rock and a hard place. You want to keep the system in operation for the sake of your usership, but you also recognize your obligation to society in general, which says that you must remove the platform for his vulgarity. Here is a situation where the support of your usership is imperative. Working hand in hand, even a situation as bad as this can be solved. Methods are covered in Chapter 4-1, dealing with interference problems. Right now, it is imperative to remember that you are not alone. Regardless of the type of system or the band upon which it operates, you will always have "neighbors," and people will always be watching you and your group. It is a direct obligation on you and your system to always project a positive public image, and there is no way for you to do it alone. The aloof system owner, whose only interest is in system hardware, is destined for user problems and eventual system failure.

Do you, as a system owner, have the right to control the content of communication over your system? Have you the right to censor what others say? When it comes to your station, yes you do. Why? Let's use a rather obvious analogy. For a moment, let us imagine that another Amateur is at your house, and you have given him permission to use your home station. You walk into the shack where he is operating and note that he is embroiled in a bitter on-the-air argument with another. You tell him to "cool it" and sign clear. He ignores you and proceeds with his dispute, signing his call portable at your station. What would you do? Pull the plug and escort him to the door? Possible expell him bodily from your premises? That radio in your shack is your station and nobody other than you, with the guidance of the FCC's Rules and Regulations will determine its use.

A repeater, or other relay device, that identifies with your callsign is as much a station as that which is located in your shack. The fact that it is located atop a mountain some distance away does not lessen your responsibility in regard to what other Amateurs communicate through it. Its day-to-day use by others in no way gives them the right to verbalize in manners of which you disapprove. You, as a system operator, are providing a voluntary service to your fellow Amateurs. An Amateur relay device is not a public utility in the eyes of the FCC, and must never become that in your eyes or that of your usership. You, and only you, have the final say over all aspects of its operation for as long as it operates under your license.

Further, an Amateur license is not a "right," but rather a privilege that is granted to you and all other Amateurs. It carries no First Amendment rights in regard to freedom of expression, and a number of times Amateurs have found this "privilege" removed when they violated some of the regulations.

Again, this does not mean sitting by the switch twenty four hours a day. If, from the outset, you establish some simple and livable guidelines, and make it clear to the users that such are being established for the good of all who may use the service that you are providing, then major problems which force you to exercise this censorship power should be few and far between. It is rare that a system owner, either directly, or through his control stations, must act to curtail certain conversations. However, when such does occur, it must be understood that such is indeed a system owner's prerogative, and that there is no recourse on his decision. A smart system owner recognizes the power he possesses, and uses it very wisely.

SYSTEM RULES

Speaking of system rules, another taboo is to over-regulate your system to a point which makes operation on it dull, trivial, and mundane. Any rules that you feel are necessary to your system's normal operation should be short, to the point, with no room left for individual user interpretation. Complex rules tend to become ambigious and bureaucratic in nature, and can eventually lead to dissent throughout the ranks. It has proven worthwhile for system owners to work with the usership in determining system operating policy, thereby giving them some say in management. This tends to instill a sense of pride in those who utilize the facilities, and leads to the type of moral support necessary in times of crisis. No system is stronger and more likely to succeed than one on which owner and users are aligned toward a common purpose. Also, such systems require the fewest rules governing their operation.

I have no intention of listing my own personal rulebook for system operating policy. It has been done well enough over the years, including just about every source from the ARRL on down. There are probably as many sets of system-operating-rules as there are systems, and in each case, what was evolved was to fit the particular situation. Trying to generalize or standardize such rules nationally is an impossible task. In the end, common sense is the best overall guide, and system owners who exhibit this behavior trait are the ones whose systems survive and prosper.

Is there any way to ensure total user compliance with your policy? No. You are dealing with human beings, and each individual has different likes and dislikes. What nine people agree with, a tenth may turn his nose at. This does not make him some kind of bad guy, nor does it mean that such a person is a detriment to you, your system, or the Amateur service. Never belittle someone on the air because he disagrees with the way you are running the show. Nor is it wise to spend hours of system time engaged in long-winded dissertations on some minute point of policy. This tends to get others upset, and can lead to discontent. If you have a disagreement with a user, take it up with him on the phone or better yet, meet at the local coffee shop and discuss it face to face. Keep such a meeting one-on-one, as large groups tend to bog down such conversations and generate no decisions. It is always possible that he may have a valid point, and one of your obligations is to listen. If he is wrong, then you must expend whatever effort is necessary in proving this to him. If he is right, you must never be "too big" to accept his viewpoint. Being able to communicate is an important part of being a successful and respected system operator.

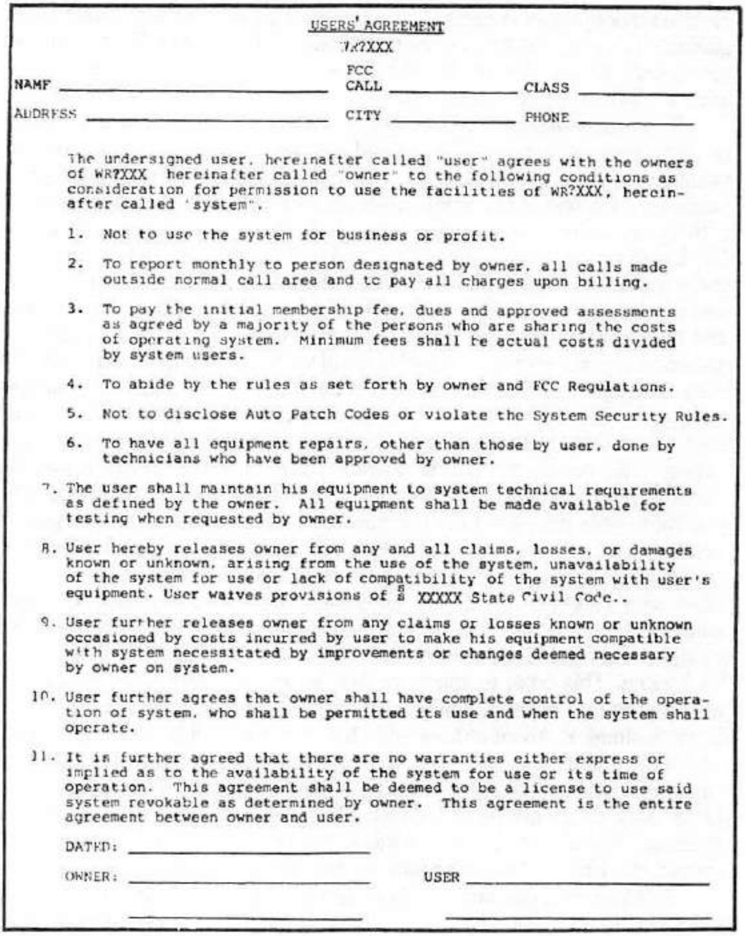
One approach being taken by some "Private-system" owners is to have all those utilizing the relay facilities sign a "User's Agreement" such as the one shown in Fig. 39-1. As you will note, it clearly defines the obligations of each party in regard to system operating policy, and in fact a binding contract between the two. Before running out to photo-copy it for use with your system, it is wise to remember that such a User Agreement is only viable for repeaters or systems which have a stable non-transient usership, i.e., closed and private systems. Trying to do this on open systems, where user hip is constantly changing would be impossible at best.

Such agreements are not cure-alls, since we still must deal with a human element as previously discussed. The agreement will help guide the day-to-day operations, but it will not help if someone happens to go off the "deep end," except perhaps to rid your system of the problem more quickly than if no such agreement was in power. Finally, this particular agreement was drawn up by an Amateur who is an attorney, and is valid within the scope of the laws in the state where he is licensed to practice. It is not a blanket outline, as laws vary from state to state. If you or your organization find this concept to be something you might like to try, then contact an attorney in your area and have him draw up an agreement which conforms to local statutes.

Never permit your system to become the most important aspect of your life. Amateur Radio is a hobby and nothing more. An Amateur relay device is a definite accomplishment in your personal life, but its establishment and ongoing operation must always be kept in proper perspective. Many of us have heard tragic stories about family units which have dissolved due to an insane dedication to a hobby, be it Amateur Radio or any other. Ownership of an Amateur repeater with its many ongoing responsibilities can place a strain on some people, which they cannot bear without affecting some other part of their life. After involvement for a while, it is easy to lose a sense of perspective, and devote far more time to such a project than initially intended. If someone ever points this out to you, listen to them. When you are involved, it's sometimes hard to see the forest for the trees. Outsiders sometimes see things we can't see for ourselves.

Possibly the most frustrating thing a system owner can do to his users, either directly or through a control operator, is to make the statement during the QSO of another that those now in QSO should sign clear so as to permit other stations to use the system. Not only is such frustrating, but it is quite rude to those using the system. Why? Let's look at the logic behind the statement. If a repeater is in use, and others want to utilize the facilities, they are going to break into the QSO in progress and request it. I have yet to meet an Amateur too timid to do so, and if any that timid exist, they are not the type who you will find using a repeater at anytime. Therefore, does it really make a bit of difference if people are talking via the repeater or if it lies silent for hours? At least when it is in use it serves a purpose. What does it accomplish when it is dormant?

Another useless owner statement is: "Keep things brief so the channel will be clear for emergency use!" True, repeaters handle many emergencies during the course of their lifetime, and during such time, only those stations involved in handling the situation should be using the facilities. At other times, this just does not make any sense. It assumes that the repeater will be handling emergencies one after another. In real life, such



USERS' AGREEMENT

WR?XXX

NAME ______________________ FCC CALL ______________ CLASS ____________

ADDRESS ____________________ CITY ______________ PHONE ____________

The undersigned user, hereinafter called "user" agrees with the owners of WR?XXX hereinafter called "owner" to the following conditions as consideration for permission to use the facilities of WR?XXX, hereinafter called 'system".

1. Not to use the system for business or profit.
2. To report monthly to person designated by owner, all calls made outside normal call area and to pay all charges upon billing.
3. To pay the initial membership fee, dues and approved assessments as agreed by a majority of the persons who are sharing the costs of operating system. Minimum fees shall be actual costs divided by system users.
4. To abide by the rules as set forth by owner and FCC Regulations.
5. Not to disclose Auto Patch Codes or violate the System Security Rules.
6. To have all equipment repairs, other than those by user, done by technicians who have been approved by owner.
7. The user shall maintain his equipment to system technical requirements as defined by the owner. All equipment shall be made available for testing when requested by owner.
8. User hereby releases owner from any and all claims, losses, or damages known or unknown, arising from the use of the system, unavailability of the system for use or lack of compatibility of the system with user's equipment. User waives provisions of § XXXXX State Civil Code..
9. User further releases owner from any claims or losses known or unknown occasioned by costs incurred by user to make his equipment compatible with system necessitated by improvements or changes deemed necessary by owner on system.
10. User further agrees that owner shall have complete control of the operation of system, who shall be permitted its use and when the system shall operate.
11. It is further agreed that there are no warranties either express or implied as to the availability of the system for use or its time of operation. This agreement shall be deemed to be a license to use said system revokable as determined by owner. This agreement is the entire agreement between owner and user.

DATED: ______________________

OWNER: ______________________ USER ______________________

______________________ ______________________

Fig. 39-1. A sample "User's Agreement," as used by some closed or private repeaters (courtesy of N6AHU).

occurrences are few and far between. Also, in the real world, if a ham happens across an emergency situation, he will let everyone know about it—quickly! Even if it means breaking on top of another amateur in QSO to get some attention. No, this isn't what one would call "A-1" operating procedure, but it sure is effective. How many times has it happened on your system? There is a far better way; a way that makes a lot more sense. Simply set your system logic in a way that forces stations to standby at least one second between transmissions. Many systems program a beep or whistle to indicate that the next user should proceed. Others simply state this as policy and design the hardware to enforce this policy. If a user "jumps" this time period, the system simply shuts down for the duration of his transmission. A one second delay timer combined with two to three minute timeout timer creates a smoothly running system with built-in user guidance. During that time, even the weakest user can break, and if it is an emergency he can declare it. The five-second over-ride assures he will have a window for his break.

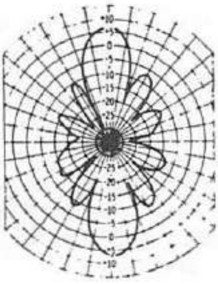
The final owner policy-statement I want to discuss is that of an owner or control operator stating "Please end your QSO. You are using up to much valuable repeater time!" Let me relate an incident that happened some years ago. On one of my many cross-country journeys, I was listening to activity in the area I was driving through. In those days, I used a Regency HR-2 with ten popular repeater pairs and two simplex channels in it. I knew there was a repeater on this particular channel. I had heard it key up and identify several times in the hour or so I had been listening. It was midday, and there was no activity. Finally, a station came on, signed his call, and stated he was monitoring. I called him and we began our QSO. I intended to stop overnight in his city, and we had been talking for about ten minutes when either the owner or a control operator broke our QSO—obviously on some form of control audio link—and told us to end our QSO, that we were "using up far too much valuable repeater time." I do not know if it was the shock of his statement, or something else, but I retorted, "How much do you value your repeater time per minute? Let me know and I'll be glad to send you a check to cover the amount. Also I need your name and address so I know where to send it. "He never responded. Rather, the speaker was filled with laughter of various intensities and from obviously different sources. I quickly reckoned that my QSO had a far larger audience than I thought. This lasted but a short time. In less than a minute the "Voice" was back again. This time, to announce that he was shutting down the system until he felt that order had been restored. This he did, and I went over to listen to simplex. About an hour and a half up the road, I finally made contact with someone in town who in turn went over to the repeater's output and, running simplex, was able to bring my QSO to 146.94. We continued our QSO there until I arrived at the local Holiday Inn where I retired for the evening. When I left in the morning, the repeater in question was still turned off. I never heard it again on that trip.

As a footnote, on a similar trip some years later I happened through the same city and, remembering the incident, I moved the channel selector of the Icom to that frequency. What a change—where only a few years earlier there was almost no activity, this time the channel was loaded with QSO's. It was near suppertime, and everyone was obviously enroute home. I listened for better than an hour as I drove away from its coverage. Throughout the hour, activity level was high and not once did I hear the "voice."

What can we learn from this? Simply, the only valuable time to a repeater is the time that users spend on it. If you are one who truly feels that there is a specific value to the operation time of your system, then you should not own one—at least not an open one. It is the user who makes or breaks any system, and people like you and I exist only because they permit us to. We are expendable. If we go away, someone else will take over where we have left off.

When we look at these three owner statements in the context of the real, everyday world they begin to look quite silly. None of the three have any real value, nor do they accomplish the end they were meant to. Any or all of the three can be replaced with a simple request to wait a second between transmissions. The end result is the same, and fewer feelings will be hurt. If activity level on your system is too high, then two simple timers will enforce your word, and you will never have to be bothered by the situation again. Think of how much you will save on aspirin!

To end this chapter, let us always think of how the other guy feels. Let's put ourselves in the users shoes and see what he sees; feel what he feels. If we like it, fine. If not, then it's our responsibility to do something about it so that, if we were users, we would feel comfortable.



Chapter 40

Handling Willful and Malicious Interference

When Ken Sessions wrote the first repeater and FM handbook, he stated that once operational, a system owner should take a hands-off attitude and walk away from trying to control system-user operation. While that attitude may have sufficed in 1969, it no longer holds any water. This is especially true in crowded urban area's where malicious interference has become almost a way of life. The fact is that this form of interference must not be tolerated by either the system owner or the Amateur community. Those perpetrating such indignities must be weeded out, and action of a legal nature taken to terminate their activities. It is the direct responsibility of every law-abiding Amateur, be he system owner or spectrum user, to concern himself with this problem and act accordingly.

In preparation for this book, I interviewed Joe Merdler N6AHU. Joe is an Advanced Class Amateur, an Attorney by profession, and moreover he is an individual dedicated to solving the willful and malicious interference problem plaguing so many repeaters today, and growing at an alarming rate.

The statements contained herein are generalities meant to serve as a guide and do not apply to any particular case. Should you desire to proceed with legal action in any cases, it is advised that you seek the guidance of an attorney in your area, competent in handling matters of this type. The following is not to be construed as legal advice, rather to be looked upon as a general discussion of a major problem.

TYPICAL QUESTIONS

- Q: Our repeater is being plagued by malicious interference. Sometimes it gets so bad that nobody other than the jammers can use the system. What is the first step we take in solving this problem?
- A: The first step is to locate the source of the intentional interference. That involves direction-finding and actually proving, with a field-strength meter, the particular location where the jamming is coming from.
- Q: Figuring we will be going to the government for help, either the FCC or another government agency, what proof will the government want from us?
- A: First, the government will want proof that will stand up in court. Amateurs cannot act as agents for the Federal Government. However, if proof can be provided as to a flagrant enough violation of the regulations taking place, it has been my experience that the Federal Government will take action by sending out their field engineers to observe and make a

record of the problem themselves, so that the Commission can proceed with some form of action, such as license revocation, or possibly criminal action through the U.S. Attorney's Office.

• Q: Obviously, we will therefore have to do the initial investigation. What do we do to properly document the evidentiary material we collect?

• A: First, those involved in the direction-finding of such problem stations must be able to prove the accuracy of their equipment. You must be able to prove accuracy of a magnitude that shows that you were able to trace the signal to its purporated location beyond any reasonable doubt.

In some cases, direction-finding has shown a specific location, such as a home. While the individual therein was allegedly jamming a repeater, an Amateur has gone to the door and rung the bell. He, and others, heard the doorbell ringing over the repeater and then the jamming ceased. In a case such as this you have fairly conclusive proof in that the Amateur could testify that he located the source of interference at a given time and did ring the bell, while others could testify that at the same given instant the sound of a bell was heard over the repeater.

• Q: What about documenting this and other actions on audio tape?

• A: Tape recording of such actions is, of course, a good way of proving them, so long as the tape itself is *clean and unused* so as to preclude any question of "doctoring."

There is a question and a caution that everyone must bear in mind. Section 605 of the Communications Act of 1934 prohibits the revealing of the content of any communication. It does exempt Amateur Radio communications from this provision. However, there are many attorneys that have taken a position that this provision in the law makes an unconstitutional distinction between communications between Amateurs and communications by the holders of other licenses in other services: i.e., Business Radio or Citizens Band. Why should amateurs be subject to what might be termed "Unlawful search and seizure?" This without a Search Warrant. Meanwhile, other people are operating under different licenses and services, without any where as strict technical requirements and are covered by these guarantees.

• Q: At the moment such is then legal. Should we tape such on-the-air problems as evidentiary material?

• A: On the face of it, the law says such is legal. I happen to feel that it is questionable, and therefore I would advise this only in instances where you plan to proceed and show conduct of such a magnetude (violation) that it would allow you to say that what is transpiring is certainly not under the protection of any constitutional guarantees.

I want to point out that taping of Amateur conversations is not illegal. The revealing of the content of the communications is what constitutes a possible illegality. If you tape such, and keep them in a log library, and do not reveal them to any one until and unless ordered to do so by an Administrative Law Judge, you have broken no law. If a Judge orders you to reveal them, then you are acting under judicial authority by his directive.

• Q: We have out initial documentation and evidence. Where do we go from here?

• A: First, the conduct must be logged. Everything you have done; every minute step must be totally and completely documented. This includes (but is not limited to) dates, times, places, beam headings in degrees, and type of interference noted. At this point, you are in a position to present a case or solicit a request for a case. That's where you have to get the support of everyone on the system, and for them to say to go ahead and do something about the situation. You will want to generate individual letters addressed to the FCC engineer In Charge of your district, explaining the specific problem. You do not want petitions, i.e., a letter drawn up by one individual and signed by many. That has little impact. The Engineer-In Charge is the person who must take the action in these cases, and it will be the individual complaints rather than one collective complaint that will bring the matter to his attention.

It should be noted that interference that occurs during times of emergencies is usually handled quickly by the local FCC Office, however, it will probably take some form of intensive effort on the part of local Amateurs to get the FCC to act in cases where the interference is to normal routine communications. It's in these latter cases where the documentation process is important and must be followed. The local Commission people will be looking to see what type of support they are getting from local Amateurs before they act.

Your first complaint must be filed with the FCC, if the problem concerns Amateur communications and interference thereto only. If there is some other conduct involved; such as threats against individuals or high-ranking government officials, then that might bring other government agencies into the picture.

- Q: What about the overall conduct of our system users? Is it proper for them to retaliate in kind to the abuse being forced upon them?
- A: First of all, any Amateur who talks to an unidentified station is presumed to have violated Part 97. It is unlawful for an Amateur to talk to a station on the air who is not identified as another Amateur station. Unless that station does identify, you must presume that he is not an amateur.

I should point out that people who live in glass houses shouldn't throw stones. If you are going to complain to the FCC about someone's on-the-air conduct as being reprehensible, then the conduct of those making such a complaint—the system users—must be above reproach. If you retaliate in kind, then you are both guilty of the same poor conduct, and the FCC will view it that way.

- Q: We have lodged our complaints with the FCC. We wait a few months, make followup inquiries, and come to realize that the Commission is not getting worse. Where do we go next?
- A: First, it is my opinion that any action undertaken must not be taken in the name of any one individual, because of the extreme personal liabilities involved should the case be dismissed from court, or the case, then there may be some insulation, for the individuals who are officers and members of the corporation, from countersuit should things not go the way you hoped. Never place yourself in a position of personal jeopardy simply because of wrongfully accusing another of something that would leave you liable to legal counter suit.

You are going into court and you are going to have to prove that a nuisance problem exists, asking that the court take action because of this nuisance. Bear in mind that the court may view this as "trading on the words of the Constitution" and the First Amendment Freedom of Speech rights.

The court is going to be very careful before it imposes sanctions against anyone accused of jamming, or proported to be the cause of such.

- Q: What do you mean by "valid corporation"?

- A: A valid corporation is one which complies will all of the laws governing its operation in the particular state in which that corporation exists. For example, a California corporation is governed by California State Corporation Law. These laws and the requirements therein differ from state to state.

- Q: What Court should we take our case to?

- A: It is my opinion that these actions must be filed in Federal Court. There are some exceptions however. In New York State, the Court of Appeals has held that the Local State Courts may take jurisdiction in matters in the pervue of the Federal Government (such as Amateur Radio) if there is sufficient interest on a local level to allow that court to act. They have held that cases of interference are of sufficient local interest to give that states courts jurisdiction.

California, on the other hand, has stated in a recent case (a tower-ordinance case affecting Amateur radio) that it was not the perogative of the state of California to usurp the pervue of the Federal Government. That local jurisdiction cannot issue frequencies or set power levels or control radio interference. These are strictly problems within the pervue of the Federal Government. Past Federal action on these matters has preempted action by local governments.

Note: Throughout this text the term "Court" is applied to any such legal body, be it local, state, or federal. There is no best answer as to which way to go. It is known that "Civil" rather than "Criminal" action will meet with better success. The problem is new, and few precedent solutions are in the law books from which to draw. It is this author's opinion that only time and court actions on all levels will set the necessary precedents.

- Q: How does one go about handling such a case?

- A: You will need an attorney; preferably one well versed in communications law, and/or Amateur radio. To expect an attorney to learn what Amateur Radio is about, with all its problems, and doing so second hand, will put him at a serious disadvantage. However, you *must* have a competent attorney to handle the problem. These are very very difficult cases and should be handled by people properly trained.

- Q: Should the repeater club corporation try to contact the offender and mediate the dispute before setting its sights on court action?

- A: Yes. Once you have your case altogether and ready to go, I think it might be prudent to contact the individual and see if you cannot avoid the difficulties of a court action by arriving at some mediation of the dispute.

However, the thing I have to caution you on is the tendency of people on Interference Committees to become vigilantees, and to take the law into their own hands. Bear in mind that the destruction of another person's Amateur equipment or an Amateur Radio station is a Federal crime, and therefore an Amateur who perpetrates such acts is violating the law. The guy you are up against might be the worst jammer in the world, but if you or your crew pull down his antenna, you can be prosecuted for it.

- Q: We are going into court on the problem. Federal Court. What is the procedure we follow from here?

- A: Obviously, the first step is to try to get either the FCC or the Federal Attorney to act. It's far less expensive to have the U.S. Attorney and Federal Government bear the cost of proving the case. Otherwise, you will have to follow normal Federal Court procedures, and bear all costs.
- Q: What action are we looking for the court to take?
- A: A temporary injunction, and a hearing to determine if the injunction should be made permanent. Bear in mind that, dependent upon the conduct involved, the likelihood of a permanent injunction may be slim—again, due to the Constitutional questions involved.
- Q: Have there been any such cases, and what has been the outcome?
- A: As of mid 1979 there have been some prosecutions. There have been no cases filed in Federal Court, although in New York there was one damage suit filed against a jammer, for a nuisance, and in that case there was success. The one thing that is apparent is the total lack of interest on the part of the Amateur community. The total lack of concern—the "let Jack do it" attitude. In one case that I know of, out of hundreds of Amateurs that were damaged by a jammers conduct, only eight saw fit to write letters and four saw fit to show up in court when sentencing was passed.
- Q: Suppose we win. The court orders the perpetrator to cease and desist. He does not comply. What then? Are we back to square one?
- A: You must provide the court with irrevocable proof that the same person is at fault. The proof must equal the original proof, and therefore any previous documentation technique used should be employed here again.
- Q: Is there any liability insurance we can take out to protect ourselves should the case fail and our corporate veil be pierced in a countersuit?
- A: No. The filing of a law suit is in itself an intentional act, and there is no way to insure your liability for an intentional act. If the corporate veil were pierced in a countersuit, then each member of the corporation would be liable, and incur liability should this corporate action be deemed an invalid corporate action.
- Q: This seems to be a long, drawn-out process. I suspect that it will only be used in extreme cases. Are there any other quicker, alternatives?
- A: The only process I know of within the law is this. If the FCC refuses to act, you have no alternative other than court action yourself.

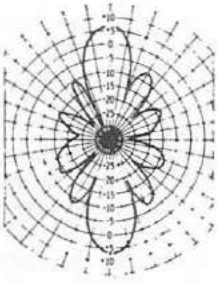
SUMMARY

"I feel that malicious interference is a peculiar problem, in many instances, done by a demented person or an angry person. If that source of anger can be found perhaps there might be many other ways of solving the problem. I will say that many problems can be solved by the parties involved sitting down and discussing the problem and attempting, as rational Radio Amateurs, to reach a solution. This for the good of the Amateur service. I believe this must be the first step taken in any program to solve a jamming problem.

I think the question must be asked—by the people handling the malicious interference problem—is what we are doing in the best interest of Amateur Radio? If so, go ahead. I think, however that you must first be critical of yourself before being critical of others."

Again, let me remind you that the statements contained herein are generalities, meant to serve as a guide, and do not apply to any particular case. Should you desire to proceed with legal action in cases of this type, it is advised that you seek the guidance of an attorney in your area, competent in the handling of matters of this type. TAB books, nor Joe Merdler, N6AHU, assume any responsibility for your use of the information contained in this chapter, and assume no liability in that regard.

It is sincerely hoped that problems with willfull and malicious interference never reach a point were Amateurs will be taking other Amateurs into court over the problem. However, it has happened, and will continue to happen until such time that all Amateurs of good will refuse to tolerate such operations. If we simply turn our heads and take a disinterested viewpoint, we are headed for anarchy, and eventual regulations that will spell the end to open Amateur repeater communications. If that comes to pass, those who did the least to solve the problem when it first appeared. The jammers could simply sit back, knowing that they had won.



Chapter 41

Repeater User's Guidelines

Just as a repeater owner has certain direct and implied responsibilities, so does any amateur who operates through a relay device owned by another. In fact, the burden on the user may be far greater than on the owner/operator. Why? Because it is you who give any system, regardless of its format or operational category, its reason to exist. You give it life, and without you, it has no reason to operate. A relay device is what you make of it, and therein lies a very clear responsibility to it, to your fellow amateurs, and to yourself.

Ever hear another amateur referred to as a "good user?" Does this mean he blindly follows the dictates of a system owner without question? No. Does it infer that such an individual obeys any regulations set before him? Not really. It does mean that such a person exhibits a proper sense of responsibility in his day-to-day operations. This is true if he is on a repeater system, operating point-to-point simplex on VHF, or chasing a rare one on 20 meter SSB. In essence, being a "good user" is synonymous with being a good all-around Amateur.

As we stated in the previous chapter dealing with system ownership responsibilities, there are probably as many sets of system operating procedures as there are systems. Some are simple, others are highly complex. Each such operating "rulebook" was designed to fill the needs of a given system in particular situation. Theoretically, your obligation is to follow such system procedures while using it. This is not to say that you should not question something that you feel is improper or unfair. If you feel that way, you definitely should, but *not* by starting an on-the-air discussion of the point. This only tends to polarize people to one side or the other, and a dispute between you and the system owner should involve only the two of you. Common sense dictates that such always be the case.

Again, let's return to the analogy we used in chapter 39, only this time, view it from the standpoint of the individual who is operating the station of another amateur and signing both your callsign and his. He objects to the content of your communication over his station and you disagree with his view. He acts unilaterally and removes your ability to further use his station for what he deems your improper conduct. You verbalize your objections further and are asked to leave the premises at once. The question now arises, did he have the right as he did?

Let's examine the circumstance carefully. Though you hold a valid amateur license which grants operating privileges for certain modes and bands, it in no way gives you the authority to use the station of another Amateur if he objects to your doing so—for any reason. In this case, you were operating his station from his premises, and you are totally subject to his wishes as to what you can and cannot do with it. You have only two choices: Either you follow his directive or you leave.

Let us apply this to an amateur repeater. A relay system is licensed to an individual as part of his operating privileges under current FCC rules, and is considered to be as much a part of his station as any equipment in his home; there is no distinction between the two. Therefore, any rules that govern his home station also govern his repeater, remote, or what-have-you. Yes, there are some special regulations as to relay system operation, but these are "in addition to" rather than "in lieu of" the basic FCC Part 97 regulations. Based upon this, the same right to control the operation of others utilizing his home station also apply to that of a relay device which he operates.

WHO'S RESPONSIBLE?

At this moment, let us digress and determine who is responsible for what is relayed over a system. Years ago, it was very specific and spelled out in black and white: A system owner was responsible in total for any communication content over his relay device. In the mid 1970's this was changed, and the burden was first placed equally on the user and owner, and eventually transferred to the user alone. This held until the deregulation of 1978, which seemed to make much of what had been said before somewhat ambiguous. Most system owners seem to feel that the current regulations have again placed the burden of content of communication in their lap, and as of early 1979, the Commission has yet to issue any clarification on this point. In time, perhaps we will know their thinking, but for the moment, most system owners have taken the view that it is indeed their responsibility and therefore they guide their systems accordingly.

For a moment, let us assume this to be true—that the system owner is the sole part responsible for anything said via his system. Should you, as a user, violate any of the Commissions rules while utilizing another amateur's relay system, you directly jeopardize his license and the continued operation of the system. If the system is ordered to cease operation as a result of a rules infraction that you committed, then it is a loss to many—for which you are directly responsible. Further, you might find yourself held legally responsible by the system owner for the action you had caused to be initiated against him. This has not happened—not to my knowledge, but it could, and nothing of that sort is worth the possible risk.

Let's be more realistic. Eventually the Commission will offer a clarification, and if recent trends are any indicator, it will be a liberal one. In this case "liberal" would mean that each amateur would again be the sole responsible party for what he says via a relay system. Or, it may be a dual responsibility. Nobody can read Washington's mind, especially this writer. Frankly, their pre-deregulation definitions *may* still be the interpretation in force today. This being the case, you may be directly held responsible for rules violations made via a repeater or other relay device, in the same way as you are held liable for violations in other aspects of your amateur operation. Operation outside the rules as set forth by Part 97 can cause action to be taken which might take away your privilege of continued amateur operation.

Why discuss this at all. Already, I've stated that common sense is the best regulation one can apply to relay operation or any other part of one's amateur career. Simply because amateur relay devices in general, and FM repeaters in particular, are somewhat different from other aspects of our hobby. Their channelized nature makes them an immovable force; one cast in concrete, so to speak. Unlike individual amateur stations, they cannot come seeking you. You must do the searching, and most amateurs eventually find a system that suits their particular needs and desires. One finds a home where he or she is likely to spend many operating hours. FM repeaters tend to attract crowds which are called its usership, and within that structure will be found as many divergent personalities as there are users themselves. The usership of a repeater is a mini-society unto itself, and as with any society, there will always be some who emerge as leaders. The problem is that there can be but one leader, and that is always the person who owns and operates the system itself. When others try to take advantage of the extended communication capability afforded by the repeater in order to challenge the owner's leadership, or to berate others, he or she is doing all a disservice. A usership which tolerates this type of operation from a vocal minority leaves itself open to disaster. Should the system owner find that this is not to his liking, or that it is detrimental to the overall good of the amateur service, he may simply take the system out of operation and turn his interests elsewhere. He is under no obligation to provide an ongoing service to anyone, and should he decide to terminate operations, there is no recourse but to look elsewhere for a repeater.

A repeater or similar device will only survive because you show it support. This means moral as well as financial. It is easy to forget that you are operating through equipment that constitutes the amateur station of another, and come to think of a system as being part of the landscape—that the repeater comes with the band, or was built into the radio you purchased. It is wise to take a step back now and then and try to view things in perspective. Ask whether my individual operations are of benefit to our Amateur community, or are my actions detrimental to it. Self evaluation is one of the best ways to improve ones operating habits and, if others have mentioned that your methods and on the air procedures are such that they find them somewhat irritating, then such evaluation is a necessity. It's one thing if another mentions an occasional boo-boo on your part. This happens to all of us once in a while. However, if everyone is always on your back, then a look in a convenient mirror is called for.

Your on-the-air behavior may be scrutinized further than you think. There are probably twice the number of SWLs listening to any repeater as there are users. This is due to an ever increasing use by the public of anything from $10 public-service radios to sophisticated scanners costing several hundred dollars. The fascination is growing, and each day brings new listeners who just may be thinking of becoming Amateurs themselves. Years ago, they listened to powerful signals talking worldwide on AM. Then, Amateur communications went SSB, and much of the audience was lost. With the advent of VHF/UHF public-service receivers of various types, the appetite to listen was whetted once more. Since such receivers afford coverage of portions of 50, 144, and 450-MHz Amateur bands, it's not at all inconceivable that we have a vast audience for our communications. This, then, imposes an even stronger moral value on us in that our individual operations will be the criteria with which is judged the overall Amateur service.

What, then, are your obligations as a user? First to remember that the purchase of an Amateur transceiver does not bring with it any guarantee of freedom to operate as you please. Second, a repeater is a shared system. This means yoi must always be aware that others may want to utilize its services. Simple good taste dictates that no one individual will monopolize the system to a point where it is detrimental to other users.

FINANCIAL OBLIGATIONS

There is a final aspect of system usership that is very important, but one that is very hard to discuss. It is the subject of ongoing financial support for repeater operations. Theoretically, an amateur can seek no remuneration whatever for his services. This is outlined in Part 97 of the FCC rules and regulations. There is one problem however. It takes cold hard cash to keep a system operational, and this place a direct moral obligation on each of us to support all systems we use. True, a system owner cannot solicit direct financial support for system operation. This would be a rules violation. However, there is no law which prohibits him from accepting voluntary donations, nor any law prohibiting you and me from making such offers.

Aside from this, there are various other methods of channeling funds to support a system. Closed and Private systems have a support structure based upon membership in a club or sponsoring organization. One pays regular dues as part of the membership, and out of these dues comes the necessary monies to maintain and improve system operation. Basically, the club is making a voluntary contribution to the operation of a repeater, so when you join such an organization you are not truly "joining a repeater," but rather some form of special-interest group which happens to support a system.

In areas where repeater activity is low, the same concept has worked for open repeaters as well. In such cases, the members of a special interest group or club voluntarily support the operation of one or more open systems. True, others outside the group are welcome to use the facilities, however, the ongoing support comes from the central core that makes up the club's membership. So as to be fair to any members who might not wish to support repeater activities, many organizations keep a separate fund to provide this support. This precludes any conflict of interest that might otherwise appear. In such cases, only the voluntary contributions made to such a fund are channeled to system operations.

Unfortunately, this type of operation has proven a poor choice for big city open systems, especially where hundreds of systems are in operation and are accessible to all. Enter the Voluntary User Support Group. This is a fairly new concept that had its roots in Southern California in the mid seventies. User Support Groups do not own repeaters, nor do they set any of the system's policies. They simply exist to collect voluntary contributions of both a financial and labor type, and channel such to the system of their choice. The first such group was the Mt. Wilson Repeater Association, which now numbers close to 600 members and who provide support for the operations of the WA6KOS/RPT (formerly WA6TDD, WR6ABE, WR6AMD) open-access system in Los Angeles. Directly on the heels of the MWRA, the Mt. Lee Repeater Association came into being with its objective of direct support to one of this nations oldest active repeaters—WR6ABN (formerly K6MYK). As stories of the success of these two organizations began to spread, the concept took hold, and today, many such organizations thrive throughout the nation.

The User Support Organization is possibly the perfect separation of user and owner obligations, while at the same time providing ongoing lines of communication and interaction between the two. Regularly picnics, swap meets, T-Hunts, and scheduled meetings permit the system owner to consult with his users, and gives the latter insight into the type of Captain who is running the ship. Ideas can be exchanged between the two, and any problems can be talked out and solved on an eye-to-eye basis.

The usership of open FM repeaters is always transitory. That is, there are always new people arriving on the scene and others departing from it. You will usually find a central core of ongoing supporters, but they are in the minority. The User Support Organization takes such into account, and therefore has no hard and fast dues structure. It permits absolute user freedom in selecting who he wants to support at any given time, and in no way forces him into any form of structured club membership to which he might object. He is free to express his support as he sees fit, without any external pressures which come from structural organizations. I suspect this to be the reason for the almost unqualified success of such groups.

There you have a rough idea of what are the responsibilities of all of us who use the amateur station of another. No long lists of dos and donts, but rather a discussion of how common sense and moral obligation play an important part in the survival of amateur relay communications.

REPEATER LISTS AND DIRECTORIES

As this is written in 1979, there are over 3,000 Amateur FM repeaters operational in the United States alone. Statisticians who watch this kind of thing tell me that the number may well exceed the 5000 mark by 1982. This does not include foreign relay systems, nor does it include the remote-base simplex autopatches. We are talking only of repeaters, most of which operate "open" format. This being the case, it might be pretty hard to know who is operating on what frequency in what location if it were not for a number of people and organizations who try to keep up with it all. These are the people who compile repeater lists. Such lists fall into three categories. Let's look at them. See Figs. 41-1 and 41-2.

The Local Repeater List

Probably the most accurate of any such listing because it is usually compiled and issued by the area coordinator or coordination council. These are the people assigning the frequencies, and therefore know who is actually operating, and where. Most councils supply these lists free of charge, or for a small fee, to any Amateur interested in obtaining them. An example of the Southern California "220" list is included.

The Area Repeater Directory and User's Guidebook

An expansion on the Local Repeater List pioneered in Southern California by the S.C.R.A. This is more than just a repeater list—it is a

			MOVING FROM 224 14
222 20 → 223 80	WR6ANI	LONG BEACH SIGNAL HILL	OPEN (CLOSED-AUTO)
222 26 → 223 86	WR6ANF	RESEDA	OPEN
222 28 → 223 88	WR6AUA	CHULA VISTA. SOUTH BAY	TEST COORDINATION
222 28 → 223 88	WB6ELR	L A . MT WASHINGTON	OPEN
222 30 → 223 90	WB6LHK	CANOGA PARK. OAT MT	OPEN
222 32 → 223 92	K6TZ	SANTA BARBARA. SANTA CRUZ IS	OPEN
222 34 → 223 94	WA6NTW	L A	STATUS UNKNOWN
222 34 → 223 94	WR6ASW	⊔ SANTA MARIA	OPEN - RACES
222 36 → 223 96	N6ZF	SANTA BARBARA. BDCAST PK	OPEN (WR6APS LINK) ←
222 36 → 223 96	WR6AZN	TABLE MT MOJAVE DESERT	OPEN
222 38 → 223 98	WR6AFG	JOHNSTONE PK. SAN GABR VY	OPEN
222 40 → 224 00	WB6OOO	MOVING TO SUNSET RIDGE	OPEN
222 42 → 224 02	WR6AOX	VENTURA. SULPHUR MTN	TEST COORDINATION
222 42 → 224 02	WB6TOP	LA MESA	TEST COORDINATION
222 42 → 224 02	WB6RIW	BIG BEAR	OPEN (WR6AZN LINK) ←
222 44 → 224 04	WR6APS	LA CANADA. JPL	TEST COORDINATION
222 46 → 224 06	WR6AJL	SAN DIEGO. MT LAGUNA	CLOSED-AUTOPATCH
222 48 → 224 08	WR6APR	LA CANADA. JPL	(TESTING ON 224 04)
222 48 → 224 08	K6SMM	VICTORVILLE. QUARTZ SITE HILL	OPEN
222 50 → 224 10	WR6AHX	SANTA ANA	CLOSED-AUTOPATCH
222 52 → 224 12	WR6AOE	SAN DIEGO	OPEN
222 52 → 224 12	K6MHE △	WHITTIER HILLS	TESTING
222 54 → 224 14	K6GCN	L A	CLOSED-AUTOPATCH
222 56 → 224 16	WR6ABA	MT BALDY	OPEN
222 58 → 224 18	WR6BBU	CHINO	OPEN
222 58 → 224 18	K6GXO	PALMDALE. ANTELOPE VALLEY	TESTING
222 58 → 224 18	N6ME	FULLERTON	OPEN
222 60 → 224 20	WR6ACF	SAN DIEGO. MT OTAY	OPEN
222 62 → 224 22	W6HIL	ANAHEIM (TEMPORARY)	CLOSED-AUTOPATCH
222 64 → 224 24	WR6ARI	SAN DIEGO. MT OTAY	CLOSED AUTOPATCH
222 64 → 224 24	WA6DCJ	HOLLYWOOD HILLS	CLOSED
222 66 → 224 26	N6UL	MALIBU. SADDLE PEAK	OPEN**WESTLINK T TH 8PM**
222 68 → 224 28	W6NUI	PALOS VERDES	OPEN - L A RACES
222 70 → 224 30	WR6ABR	EAST L A	CLOSED
222 72 → 224 32	WB9RNW	MT WILSON	CLOSED
222 72 → 224 32	WA6KYZ ⊔	INYOKERN. LAUREL MT	CLOSED-AUTOPATCH
222 74 → 224 34	WR6AFB	SAN DIEGO. MT OTAY	CLOSED-AUTOPATCH
222 76 → 224 36	WR6ABC	L A . LOOKOUT MT	OPEN
222 78 → 224 38	WR6AVO	PALOS VERDES	CLOSED-AUTOPATCH
222 80 → 224 40	WR6ANK	CHATSWORTH. OAT MT	OPEN
222 82 → 224 42	WR6AAA	CATALINA ISLAND	OPEN
222 84 → 224 44	WR6AOY	MONTERY PARK S. PASADENA	OPEN
222 86 → 224 46	WR6AKY	SAN DIEGO. PT LOMA	STATUS UNKNOWN
222 88 → 224 48	WR6AXD		OPEN
222 90 → 224 50	WR6ACB	ANAHEIM	CLOSED-AUTOPATCH
222 92 → 224 52	WA6VOP	L A . LOOP CANYON	OPEN
222 94 → 224 54	WR6AID	SAN DIEGO	TEST COORDINATION
222 94 → 224 54	K6PON	SAN GABRIEL VY. PUENTE HILLS	OPEN (CLOSED-AUTO)
222 96 → 224 56	WR6AUJ	RUNNING SPRINGS	OPEN (CLOSED-AUTO)
222 98 → 224 58	WA6VNV	CHATSWORTH. OAT MT	NOT ASSIGNED
223 00 → 224 60		REPEATER TESTING CHANNEL	OPEN
223 02 → 224 62	WR6ADL	HAWTHORNE	CLOSED
223 04 → 224 64	WR6AFJ	PALOS VERDES	OPEN
223 04 → 224 64	WB6TAM	NORTHRIDGE	CLOSED AUTOPATCH
223 04 → 224 64	WR6AIP	LA MESA	CLOSED AUTOPATCH
223 04 → 224 64	W6TIO	LAGUNA BEACH. TEMPLE HILLS	OPEN (CLOSED-AUTO)
223 06 → 224 66	WR6AIZ	LEMON HEIGHTS (ORNG COL)	CLOSED AUTOGRAPH
223 08 → 224 68	WR6AOR	BALDWIN HILLS	CLOSED
223 08 → 224 68	WR6AIG	SAN DIEGO. MT OTAY	OPEN-RTTY VOICE
223 10 → 224 70	WR6AYI	LAGUNA BEACH. TEMPLE HILLS	CLOSED AUTOPATCH
223 12 → 224 72	WR6APJ	JOHNSTONE PK . SAN GABR VY	OPEN
223 14 → 224 74	WR6ABJ	L A . HOLLYWOOD HILLS	OPEN
223 16 → 224 76	WR6AUT	TUSTIN. PEACOCK HILL	CLOSED
223 16 → 224 76	WA6ZSM	SAN DIEGO. PT LOMA	CLOSED
223 18 → 224 78	WA6AKJ	L A . HOLLYWOOD HILLS	CLOSED AUTOPATCH
223 20 → 224 80	WR6AOV	SANTIAGO PEAK	RTTY ONLY OPEN
223 22 → 224 82	WB6CYA	SAN DIEGO MT OTAY	CLOSED AUTOPATCH
223 24 → 224 84	WR6AUG	L A . HOLLYWOOD HILLS	OPEN
223 26 → 224 86	WR6ACJ	CRESTLINE	CLOSED-AUTOPATCH
223 28 → 224 88	WR6AXE	MT BALDY. SUNSET RIDGE	OPEN 220 CLUB SAN DIEGO
223 30 → 224 90	WD6HFR	SAN DIEGO MT PALOMAR	OPEN
223 30 → 224 90	WB6RHO	THOUSAND OAKS	CLOSED-AUTOPATCH
223 32 → 224 92	WA6POI	MT PALOMAR	CLOSED AUTOPATCH
223 32 → 224 92	WR6AWS	PALOS VERDES	OPEN
223 34 → 224 94	WR6AJI	MT WILSON	CLOSED AUTOPATCH
223 36 → 224 96	WB6VTM △	SAN DIEGO. PT LOMA	OPEN
223 36 → 224 96	WR6AYY	L A	(CLOSED-AUTO)
223 38 → 224 98	WR6ATB	MT WILSON	CLOSED AUTOPATCH

△ NOT COORDINATED BY SPECTRUM MANAGEMENT ASSOC (TWO-TWENTY)
OUTSIDE BOUNDARY OF SPECTRUM MANAGEMENT ASSOC (TWO-TWENTY)

Fig. 41-1. A sample of a local repeater listing. This one is for 220-MHz in Southern California.

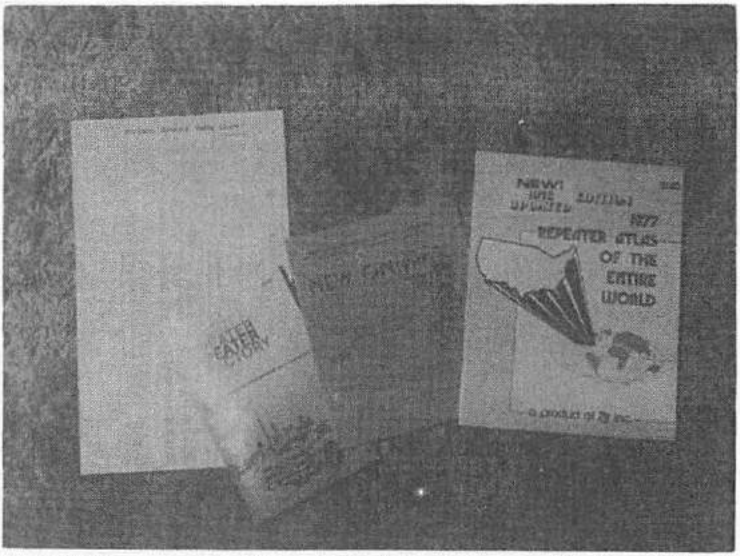


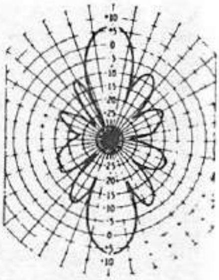
Fig. 41-2. Some repeater lists and directories. Shown are Northern California Repeater list, ARRL Repeater Director, Southern California Repeater Directory, tory, and 73 Magazine World Repeater Atlas.

complete listing of all area VHF (2 Meter and 220 MHz) activity; both relay and nonrelay oriented. Along with a complete repeater listing by frequency, the booklet also contains listings of Coordinated Remote-Base Downlinks, Simplex Autopatch systems, accredited nets (all modes), complete area bandplans for all modes, area operating procedures, explanation of system operational categories, simplex channel listings, and much more. Since it, like the Local Repeater List, is usually published by the local frequency coordinator or coordination council, its accuracy is quite high.

The Commercially Published Repeater Atlas

Currently, a number of services publish "World Wide Repeater Lists," or, as they are better known, "Repeater Atlases." One major drawback to this type of publication is that input for them is derived from the overall Amateur community rather than just the coordinators and/or coordination councils. As should be the case. Since these publishers have no way of checking on the authenticity of the input received, there are chances of erroneous listings appearing through no fault of theirs. Unfortunately, more than a small number of Amateurs over the years have seen fit to request listings of non-existent repeaters or uncoordinated repeaters. Such listings are of little value to the Amateur community other than ego fullfillment for the person requesting such a listing. It is hoped that all national/international listings services will accept only information provided by coordinators and/or coordination councils in the future, so as to negate the problem of erroneous system listing. In the interim, such lists should be considered only as a general guide to area activity, and it is suggested that local lists or directories be procured when visiting a given area.

Chapter 42
Avoiding the Rip-Off Game



Late one evening last January, Bill, KH6IAF, and I left my house to drive Bill back to Burbank. When we reached my car, we found that someone had broken into it and stolen my beloved Icom IC-22. In the many years that I have run mobile, I am thankful that this is only the second time I have lost a radio to a thief, and, hopefully, this time I have learned my lesson. The other radio lost was a Polycomm 6, in 1968 from my then two-month-old Mustang.

Unlike the last time though, rather than just flying off the handle about how poor the police protect us, I took my time to evaluate what I could do in the future to foil potential radio thieves. I hope that all Amateurs and Citizens Radio operators will benefit from my misfortune. First, let's take a look at where radios get ripped off.

From what I have been able to learn, the majority of these thefts seem to take place at night, and in poorly lit areas. "Good suburban neighborhoods" are prime targets of radio thieves. However, this does not rule out other places as well. It seems as if there are more and more daring thieves who will even attempt to rip off a radio in a heavily patrolled shopping center parking lot, and in broad daylight. What it comes down to is that if a thief really wants your radio, he will find a way to get it regardless of what precautions you take. While it is impossible to totally stop radio-rip-offs, we can make the thieves' life a lot more miserable and his job a lot harder. Let's see how.

TRUNK-MOUNTED GEAR

By far, the most "theft proof" radio that a VHFer can install in a vehicle is a trunk-mounted, converted commercial two-way radio. I have since gone this route in both my vehicles, and now sleep a lot more easily. For those of you who are not familiar with this type of equipment, let me describe it to you. These radios were designed for the Commercial Land-Mobile service, and are divided into two basic parts: the radio itself, and the control head/ mic assembly. The radio unit is mounted and secured within the confines of the trunk of the vehicle. To be a bit more specific, you first mount the radio cabinet in the trunk, bolt it to the vehicle, slide in the radio chassis, and lock it in with the built-in lock and key. Virtually every radio of this type has such a locking arrangement, and luckily, very few radio thieves have the necessary key. To remove such a radio without the key, providing it has been installed properly, is a monumental task and not one that the average radio thief will delight in.

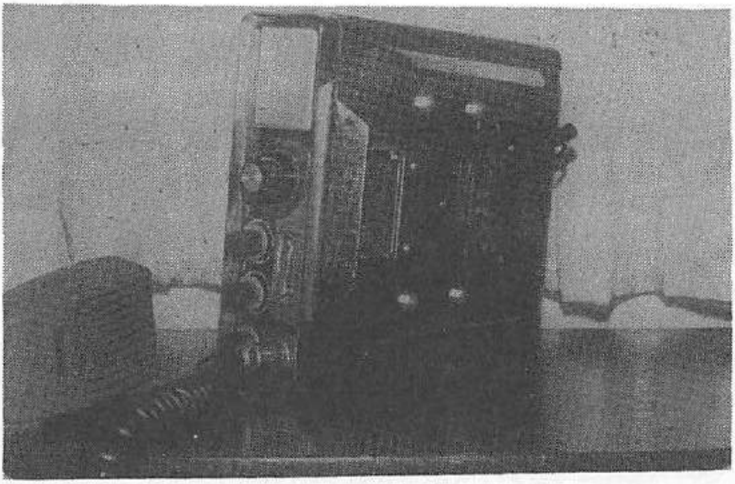


Fig. 42-1. A slide-mount can save your radio. One half of the mount fastens to the transceiver, and electrical connections go through the block.

Swell. Now you have a very secure radio installed in your trunk, but how do you make it work? Radios such as these are operated by a dash-mounted control head. An average control head is about 4 or 5 inches long, 2 or 3 inches high, and 2 to 4 inches deep. This is nothing more than a box that contains an on-off switch, a pair of potentiometers to control volume and squelch levels, and if the particular radio is multi-channel or equipped with tone-coded squelch, the appropriate controls for these functions. A multi-conductor cable is hooked between the two units, thus enabling the unit to be both powered and controlled.

While all this sounds great, there are a few drawbacks to this type of radio, but none that cannot be overcome. Since this type of equipment was designed and built for a service other than amateur, most of such radios, regardless of vintage, are single or dual channel only, and trying to add more channels can be a difficult, if not impossible, job—especially on some of the older radios. However, you might like to take the direction that I am going. While the two channels in my Motorola T43GGV suffice in my running-around-town car, I am building and installing a remotely controlled synthesizer for the X43GGT in my 1973 vehicle. The synthesizer will be in the trunk, along with the radio, and a secondary control head will house the BCD switches to set frequency. The most that a radio thief can get will be a replacable control head and a box of switches. The radio will be under double lock and key.

There is one other drawback to consider. Again, depending upon age and the amount of bread that you have to shell out for such a radio, the majority of such equipment available to the average Amateur is tube type, and a radio using tubes and putting out 80 watts can easily draw 30 amperes or more. The newer, solid-state radios cost a lot more, but do draw a lot less current for the same power output. I feel that, in my case, the security of this system overides the inconveniences, and have adopted this system, along with one other, for my vehicles. However, a friend of mine recently showed me that with very little work, there is one piece of today's two-meter Amateur equipment that can easily be removed in the same way. It seems that the Motorola Metrum II has a removable and reversible control panel. Well, this panel can be mounted in a small enclosure and cabled to the main radio unit to achieve the same end as described for the converted commercial equipment. I suspect that when I eventually replace the radios now in use, it will be with remoted Metrums. All I need is the money to purchase the radios, but that's another story. Radios taken out of commercial service are available through many advertisers and two-way shops.

Okay, you are willing to give up a little convenience, but the idea of a trunk-mounted radio really doesn't send you all that much. Furthermore, you already own a "works all channels" super-Wizzbanger and want to be able to work any repeater, any place. You know enough to always take the radio out of the vehicle, and either lock it in the trunk or carry it with you, but you hate fumbling with those mounting screws. In fact, I suspect that it is the annoyance of having to remove this type of mounting screw arrangement that causes a ham or CBer to leave the radio in the car in the first place.

SLIDE MOUNTS

A few years back, when ripping off car tape players was the "in thing," some bright manufacturer developed the ultimate "foiler" for the thieves involved in that occupation. It is a simple device known as the stereo tape player slide-mounting tray. It consists of two pieces of metal that are bent in such a way that they can be slid together and interlocked. Electrical connection is accomplished by means of copper or phosphor-bronze fingers that make pressure contact when the two units are slid together. Power, as well as connections for a tone pad, can be made through these "fingers." However, I do not advise running your antenna feed-line through this arrangement, since it can create SWR problems and lead to blown final transistors. I have one of these mounts in each of the vehicles, and should I

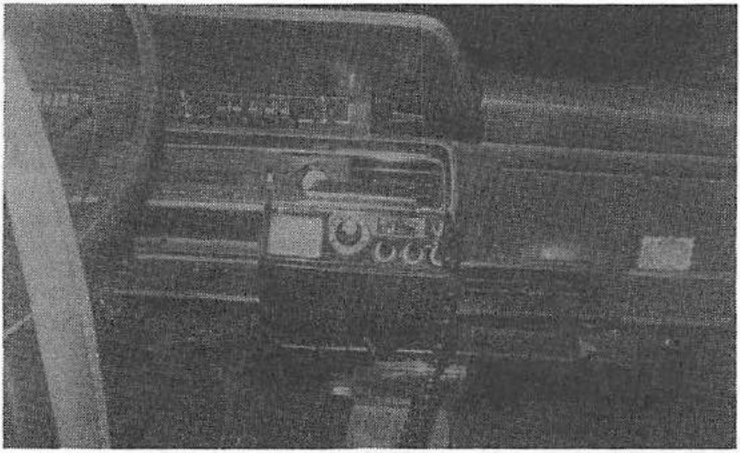


Fig. 42-2. The rig slides in place, and can be removed and taken with you in seconds.

have to travel out of this area, it takes but 5 seconds to screw the PL259 in and slide the radio into the mount; a lot easier than playing the knurled-screw game. See Figs. 42-1 and 42-2.

While the majority of these mounts do have built-in locks, and a key to secure them, I, for one, don't trust the arrangement. Therefore, since as I said it takes but 5 seconds to either install or remove a radio from such a mounting fixture, I always take it out of sight when away from the vehicle. You know what they say... once burned, twice careful. If I am not in the vehicle, neither is the radio.

You can secure the radio to the mount in a number of different ways, but the best is to secure the plate to the radio cabinet by drilling through the cabinet. If you do not wish to do this, or, if you have a radio whose inherent design does not permit this type of mounting, the next best method would be to secure the radio mounting bracket to the appropriate section of the slide mount, then mount the radio to its bracket. If you are lucky, you will be able to find a few holes in the radio bracket, and no drilling of either the bracket or mount will be necessary. If you do have to drill, try to drill the slide mount rather than the radio bracket. Another no-drilling method of fastening the radio to the mount is to use double-sided sticky tape. I do not like this idea, since under high-vibration environments such as found in many vehicles, the tape might come apart. This could lead to a rather dangerous situation if the radio should happen to come loose and hit you in the leg while you are driving. However, Bill, KH6IAF has Yaeser FT-224 mounted in this manner for a number of months now, and has used this radio and mount both here in Los Angeles and in Honolulu with no problem.

For the lazy type like me, this is probably the greatest security gadget ever invented. Besides, $5.95 plus tax is the cheapest form of insurance a ham or CBer can buy.

IN-DASH MOUNTING

Finally, if you are one of those like I used to be, and must leave the radio constantly mounted in the vehicle, then I suggest that you throw away the mounting bracket and find a way to either mount the radio into the dashboard as part of the vehicle, or at least bolt the radio cabinet directly to the dash, doing so in as secure a manner as is possible. Metric nuts, bolts, and lock washers available from foreign-car-repair parts houses are a good choice, but will not stop a thief, as experience has proven to me personally. My IC-22 was securely mounted with nuts and bolts through the top portion of the case, but from the way things looked when I discovered the theft, the thief must have had a crow-bar with him. About the only satisfaction I had was to realize that the turkey most likely destroyed the radio when he pried it free.

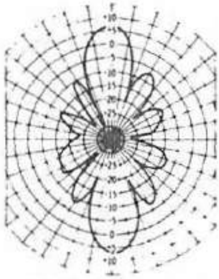
ALARMS AND SECURITY DEVICES

While I could do a whole section on alarm systems and security devices, I feel that is up to the individual owner, and will leave that department for another time. I do, however, want to discuss something else and that is radio identification. Today, most manufacturers use one form or another of stick-on tag that carries the model and serial number of the equipment. The tag can easily be removed, and with it any hope of ever identifying the radio. A simple way to get around this is through the use of an engraving pencil to engrave your callsign and drivers-license ID, along with the abbreviation of your state, both inside and outside the radio. Even if the thief is able to obliterate the marking on the back panel, he probably will never bother to take the time to thoroughly inspect inside for identification markings. If you are smart about it, you can also mark some sort of personal code inside that you alone know. A star, a little design of your own, probably will not attract the attention of a thief, but if the radio gets stolen and by some miracle it is recovered, you can use this as a positive form of ID.

Another form of "personalized ID" comes in the form of documenting all repairs and modifications you have made to the radio. As an example, say you have installed a jack for a tone pad, or a tone-coded squelch encoder, or perhaps you had to replace an original transistor with a substitute number. Document any of this in your file, and should "John Law" ever require you to prove that the radio is yours, this will be a great help. In the case of my IC-22, there are a number of such identifying marks known only to me and the Los Angeles Police Department. It will not be hard to identify that radio if it should ever show up, even if the serial tag is removed!

Finally, there is one method of tracking down your radio, should it be pilfered, that no one has ever discussed. If someone, who obviously thinks he is on 11 meters, shows up on your favorite repeater, claiming to be "Big-Knife" or something like that, how could you possibly know if he is using your missing rig. One way is through the use of Continuous Tone Coded Squelch encoders or, as it is better known in ham circles and around the Motorola Corporation, PL. Let's say that you have gone to the trouble of adding CTCSS encoders and decoders to your station. You may be using this as a way of listening for all your friends on the local repeater without having to listen to all of the system activity. Then one night your radio is stolen. A few days later you hear "Big Knife" looking for a "Breaker-Break on 4," and you are hearing this with the CTCSS decoder turned on! Chances are better than 2 to 1 that it's your radio that has turned up, and now the real job starts—that of T-Hunting, or in some other way enticing the num-num who has the radio into meeting with you (and the local police) so that it can be gotten back. That CTCSS tone is like giving the radio a verbal finger-print, especially if it happens to be a tone known only to you and your close buddies. Even if the person who has the radio decides it's more fun to jam-jam than to play "CB" on the repeater, the tone will be not only a dead give-away, but a verbal finger print for you to use in identifying your rig. In these situations, anything you do beforehand can benefit you later.

With the number of such thefts increasing, and with more and more insurance carriers becoming reluctant to issue coverage on CB and Amateur equipment, it becomes incumbent upon us to take any step necessary to provide security for our mobile equipment. It takes very little time (15 seconds!) for an experienced thief to rip off a $500 radio, and it takes you and me many weeks of work to be able to replace it. The best way of never having to do so, is to never put temptation in front of a radio thief. I hope that the foregoing will be of help to you in that direction.



Chapter 43
Special System Services

Fact: You can do more with your repeater system than just talk cross town with it! Many amateurs have come up with some rather interesting sidelights to their relay operation, and in this chapter we hope to whet your appetite for some of them. Interested? Read on! Unfortunately, the non-channelized nature of SSB translators does not lend itself easily to most of what is contained in this chapter. This does not mean that such is impossible; only a bit harder to implement.

PATCHING

An autopatch is an interconnect between an amateur relay device and the local telephone line which permits system users to place non-business calls via their Amateur stations. Note that I state non-business calls. This is very clearly outlined in Part 97 of the FCC Rules and I refer you to that source.

Of all the system ad-ons available today, autopatch is by far the most popular. However there are a few drawbacks, mainly as as result of an October, 1978, "Rules Clarification" by the Commission, which in effect killed off such operation on repeaters which operate by fully automatic remote control. While autopatch is far from dead, what we Amateurs term "Open Autopatch," i.e., autopatch on repeaters where no control stations are present, is forbidden. Where does this leave system owners or licensees who wish to have this facility on their system? One might say "up the proverbial creek."

The rules clarification was very specific. Not only did it make the presence of a control operator mandatory during times of autopatch use, but further stated that while operational in autopatch configuration, the regular Amateur station rules, rather than the rules governing repeater operation, were applicable. More simply, when used as an autopatch, a repeater isn't a repeater, but rather a normal amateur station. For an open system this can make life intolerable. Either the system owner solicits enough control stations to cover a 24-hour day, or he limits the time periods when the autopatch is available and links this directly to the control station? This is not really feasible on open systems where usership is transitory. It is, however, automatically applicable to closed and private repeaters as well as remote-bases in that the restricted system access demands that all users be control operators as well. It's only the open-system operator who has the real problem, and thus far, nobody has come up with a real solution other than a request for a change in the structure of Part 97 to allow such operation. With the close scrutiny now being placed by the Commission on all types of telephone interconnects, any consideration of such a proposal is doubtful at best.

There have been some rather ingenious attempts of late at meeting the Commission's edict. Since the rules apply to incoming (reverse autopatch, or dial-in autopatch) as well as outgoing calls (user initiated calls), at least two systems that I am aware of have deactivated the user direct-dial feature of their systems, and now have a control operator who is truly an "operator." I know it sounds funny, but across this great nation there are repeaters where one requests the use of the patch and a voice responds, "Number please. This is K7XXX Control." Or, the voice of a control station breaking a QSO and announcing, "Is WA2ZZZ on channel? There is a call for him. This is WA2HVK control for WR2XXX." Silly, yes. But nevertheless, it's happening.

OPEN-CLOSED

Another approach at preserving "autopatch" on open FM repeaters is the combination "Open Repeater/Closed-Private Autopatch," where the overall relay facilities can be utilized by any Amateur coming to the channel, but the autopatch is limited to a small group who form the basis for it's support. These stations usually belong to some sort of club (i.e., The South Bay Autopatch Repeater Club), are equipped with the necessary specialized tone-access devices, and are considered by the system licensee to be "control stations." While this has worked well in areas of low activity, or on bands where crowding is not a problem, in other cases it has been disastrous. There is an obvious risk in this situation, that of the "have-nots" becoming jealous of the "haves." This jealousy can eventually lead to friction between the two, which, in turn, means on-the-air confrontation and destruction of the effectiveness of the repeater system. This approach is strictly one of "playing it by ear" with careful attention paid to the system at all times. If you can make it work, all the better. If not, kill it right away. No peripheral is worth the destruction of the system proper. The "Open Repeater/Private Autopatch" concept is indeed a very ticklish proposition.

If you have autopatch, what are the advantages? Aside from providing your usership with easy access to a telephone for personal use, there is the overall public-service aspect. There is no way of knowing the number of lives that have been saved because an Amateur happened by and had instant access to a telephone from the scene of an accident of other disaster. Perhaps local telephone service was not in operation, but the phone at the repeater site was, thus giving phone access to disaster-relief efforts, as was the case in the 1978 Southern California Floods. There, a massive effort on the part of Southern California Amateurs was mounted, and a number of autopatch-equipped repeaters were pressed into service to help the efforts of such organizations as the Salvation Army and Red Cross. Not the first time, nor the last; just another aspect of the service Amateur Radio provides the general public.

Ever hear of the telephone number "911?" In some cities, this three-digit number connects you directly with one or more emergency services such as local police, fire, or highway patrol. In other places, one must either call the operator and request such a service or have such numbers at hand. If you operate through an autopatch repeater, it is almost vital that you carry with you a list of such numbers to give you access to emergency services. Why? Should you happen across some form of accident, or be involved in an emergency yourself, the reason becomes self-evident. In such cases, time may be of the essence, and the extra time spent in obtaining information may be intolerable. Therefore, it is advisable to carry a list of such numbers affixed to your automobile dashboard or directly on your radio.

One last word on this topic. Remember that autopatch calls where there is any pecuniary interest are strictly forbidden by the FCC Rules and Regulations. What constitutes "pecuniary interest?" Just about anything where one of the parties to the call will in some way financially profit from it. If you are not sure if the call you plan to make falls under that category or not, be wise—don't make it through the repeater. Each time an Amateur is cited for such a transgression, it is another black eye for the entire service. It also brings us one step closer to losing the privilege of telephone interconnect entirely!

ALLIANCES

Autopatch facilities are not the only way that a relay device can become an instrument by which the amateur can provide some sort of public service. In a speech made to the membership of the then Southern California Repeater Association in 1977, Herbert Hoover III, W6ZH, stated that through some sort of alliance between repeater systems and public-service organizations such as the Red Cross or Salvation Army, the overall effectiveness of an amateur relay device can be truly enhanced. This type of alliance works to everyone's benefit. The public directly benefits from a more efficient services as a result of the expanded communication facilities. We, as amateurs, benefit by utilizing our communications skill for the welfare of our fellow man, and such volunteer efforts truly enhance our public image. The nice part is that it costs nothing, other than a bit of time from each of us and the system proper. All the hardware exists. All that is needed to get this sort of thing going in your area is a phone call or a visit to an agency such as these, with an offer to provide a service. You will be welcomed, and what you have to offer will be appreciated—in many cases, by people you will never meet.

ARES AND RACES

ARES and RACES are two other organizations with which a repeater might choose to affiliate, depending upon the overall interest among the usership, and the RACES structure in your community. Here in Los Angeles, RACES is under the direction of the Sheriff's Department, and therefore uses repeaters set up according to our state's emergency preparedness program. Here, such systems are dedicated to RACES utilization only, and operate on frequencies within the scope of what has been set forth as "War Caused Emergencies" spectrum. In other locations, RACES operation is integrated with Amateur operation on normal systems that elect to dedicate time for such operations. If participating in a RACES type program interests you, but you are not sure of it's exact structure in your area, try contacting your state's "Office of Emergency Preparedness," or a similarly titled agency in your locality. They will know exactly where to direct you, and will have details on such operations in your region.

ARES, the Amateur Radio Emergency Service, is an ARRL-sponsored service to which many of us already belong. ARES has an active structure in just about every place there is some organized Amateur activity. Repeater groups are always welcome, as are the relay facilities thus provided. While the exact nature of activity varies somewhat from place to place, in general, a certain time slot is scheduled for a weekly ARES Net on which actual and drill traffic is passed, so that those involved can become more proficient in the handling of such messages. In addition, many nets issue Official ARRL Bulletins which contain information of importance to Amateurs.

Does it work? Can you initiate a piece of traffic on a VHF net and have it reach its destination hundreds or thousands of miles away? Yes, and I have used such services many times. The ARRL sponsors a National Traffic Network, and messages initiated on local nets, be they repeater or point-to-point, are filtered to this network and passed along it. The messages do get through, as I have witnessed many times over the years. If starting an ARES Net on your repeater interests you and your usership, and the system is free to dedicate an hour or two a week to such an undertaking, then contact a local ARRL official for information about starting such a service. If you are not sure who those officials are, a note to the ARRL at 225 Main Street, Newington, Connecticut 06111, will bring the information you seek. ARES and RACES are vital services, especially in times of disaster. However, to be effective means taking the time to train for such eventualities, and, in this case "training" means gaining proficiency in accurate message handling. This means ongoing practice, and is another good use of system time which can eventually benefit your community.

I mentioned that some systems read "Official ARRL Bulletins" as part of their routine operations. The ARRL is not the only source of such bulletins, which fall under the banner of "QSTs"—messages of interest to all amateurs. There are two other sources of national and international amateur radio oriented news, as well as a myriad of local news sources within the community itself. The Rules and Regulations do permit the issuance of such bulletins, as long as the content is of a nature to be of general interest to the amateur community. The issuance of such material, either via a repeater or point-to-point, in no way constitutes broadcasting. Based upon this, mnay repeater groups have taken to issuing regularly scheduled bulletins with material garnered from popular sources. The two which are most often utilized are *H.R. Report* and the *Westlink Amateur Radio Newservice*.

H.R. Report is a subscription newsletter prepared by Joe Schroeder, W9JUV, and published weekly by the *Ham Radio Magazine* news staff. Its postal schedule permits it to arrive early in the week, usually Monday, so that the contents can be disseminated on a local basis over the next seven days. Many nets that I have listened to read either in-total, or excerpt, the contents of *H.R. Report*, thus giving it wide coverage. For information on *H. R. Report*, and current subscription rates, contact the "Ham Radio Publishing Group," Greenville, NH 03048.

The Westlink Amateur Radio News is a totally different entity, see a description at the end of this chapter. It is a taped, newscast-formatted QST produced weekly in Los Angeles by an organization known as the Westlink Radio Network. Running from seven to ten minutes in length, it, like *H.R. Report* also deals with information of interest to the amateur community, but is specifically structured for issuance via an amateur repeater or remote-base system. This takes away the necessity to have an assigned "reader" to handle the weekly chore. All that is necessary is a cassette tape player, connected either directly to the system via a control link, or to a user's radio. At a prearranged time, all the station who is issuing Westlink need do is "call up" the QST and start his tape player. Everything else has been taken care of already. Best of all, the Westlink News costs only the price of postage plus an initial investment in about a dozen cassette tapes and mailers. Westlink charges nothing for its part of the service so long as you pay postage on all tapes both ways. More information on Westlink can be obtained by sending a note along with an S.A.S.E. to the Westlink Radio Network, 8331 Joan Lane, Canoga Park, California 91304.

We live in a fast-paced, ever-changing world. Events are constantly taking place which effect every aspect of our lives and our Amateur operations. Today's amateur must be an informed Amateur; he has no choice. Amateur Relay Systems can play a key role in the process of Amateur Radio related news dissemination.

LINKING

Finally, there is "linking", the tying together of two or more systems with the purpose of expanding overall coverage, and thereby accessibility, of all systems involved to areas outside their normal coverage. This idea is not new. It's been around for more years than many of you have held your licenses, and it is another operation concept which traces ancestry back to the Western United States. As far back as the late 1950s, FM experimenters in the Southwest were tying their systems together on a selective basis up and down the West Coast—to see how far they could go and, even more important, what could be accomplished once such links were established.

The concept was going great guns by the late 1960s. Then something called Docket 18803 came along and effectively killed off such intertied operations for many years. Not that it killed them off entirely. Actually, experimentation kept right on going but was moved out of the spectrum that was in"public view." Virtually all such experiments became quiet, private operations, and remained that way until initial deregulation again permitted such operations. During those "black years," when we who were interested in relay communication were literally forbidden to do anything other than "talk" within the confines of a restricted area, rumors constantly circulated of daring violations of the regulations by those who felt that the technological advancement afforded by their endeavors far outweighed any risk involved. The overall extent of such clandestine operations is unknown. Whether the rumors themselves were true is unknown, and probably always will be. There are few who are willing to admit that they were the ones who spearheaded such a movement. However, during the 18803 "reign of terror," these unknown souls became the folk heros of UHF/VHF communications within the Amateur community. I am willing to bet that, had amateur radio not been forced to endure "18803," there might exist today many "open," wide-coverage interties—possibly some going "coast-to-coast," and others operating "border-to-border." We lost our chance at this because the FCC did not understand relay communications, and by the time we had educated them as to what we were capable of doing if left alone with minimal regulation, 2 meters had become so populated that most regions could not set aside space for this purpose. 18803 has cost us dearly.

Today, there exist a far greater number of "private" interties than of the open variety. There are virtually none on 2 meters, that the average amateur can access. Most operate on either the 450-MHz or 220 MHz band, and extreme security precautions abound to the extent that some forbid open discussion of the existance of this type of operation. Why this security paranoia? I can only speculate. As stated earlier, 18803 tried to kill this type of operation. In many cases, it succeeded, while in others it simply drove it underground, away from normal Amateur circles. In time, those involved became a special interest group unto themselves, and an incursion by outsiders was deemed unwelcome. While VHF/UHF scanners have given a new spotlight to this type of activity, a wall of digital tone-access still separates many such operations from the rest of Amateur society, and I seriously doubt if such systems will ever open their doors to the masses. Don't blame those involved for this attitude. Blame 18803 for placing them in that position in the first place.

Not that all interties are this restrictive. Over the years, a few examples of regional open interties have evolved and prospered. A prime example of this is the Hawaiian State Repeater System, which provides intertied, open-relay communication throughout the entire "Island State." The Hawaiian State system is one of the oldest known operations of its type. Starting as a two-system "AM" operation in the mid 1960s, it became a three-site FM operation in the early 70s and has remained operational ever since. Even during the 18803 "reign of terror," it remained operational on special waiver granted by the FCC—one of very few which received such special treatment.

Originally designed, built, and installed by the Emergency Amateur Radio Club, it is currently run as a cooperative effort by EARC and the Big Island Amateur Radio Club. Its prime purpose is to act as a means of handling emergency traffic during times of disaster. However, operation is not limited to this. The "State System" is open to normal operation 24-hours a day, and permits Amateurs on the various islands which comprise the state of Hawaii to keep in contact with one another. There are no autopatch or phone-patch facilities on the intertie because the Amateurs sponsoring it do not feel it proper to be in competition with normal telephone operations. To ensure that the intertie, and thereby the entire state, will not be tied up with local traffic between two or three Amateurs on any given island, EARC and many other organizations, also sponsor regional repeaters for on-island operation. Thus, local matters need not tie up an entire state.

Thanks to the intertie, Hawaii is probably the only place with a statewide amateur news service. Started in 1975 by Pat Corrigan, KH6DD, of EARC, this weekly service brings quickly to island Amateurs

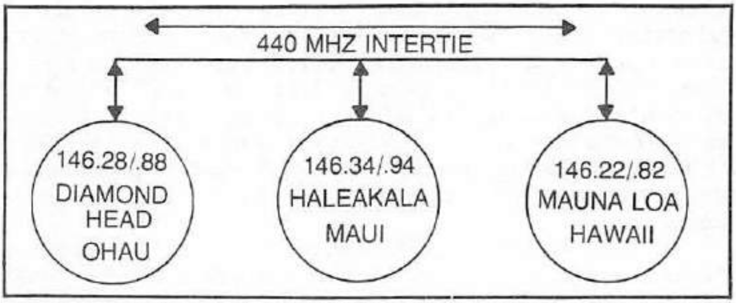


Fig. 43-1. Traditional cross-band intertie used in Hawaiian State Repeater System.

the information that might otherwise take far more time to reach them. It has become a regular feature of the State System, and has a good following, according to Pat. One might say that this is the only true Amateur-news network that exists today.

The three key systems which comprise the two meter portion of the Hawaiian State System are all on volcanic hilltops, see Fig. 43-1. One, the 146.22/.82, is possibly the only system operational from an active volcano, Mauna Loa. From 7800 feet above sea level, this system serves most of the "big island" of Hawaii. Via a 440-MHz link, it is tied to Maui and Oahu. The Maui site is on the rim of an extinct volcano called Haleakala. This system operates on 146.34/.94 and is again linked via 440 MHz to a .28/.88 machine on Diamond Head. The 440-MHz link is set up in such a way that a user accessing any one of the three is retransmitted by all. Over the years, the Hawaiian State System has proven its value, both in times of emergency and during routine operation. This system says that open interties can work, and stands as proof.

The Hawaiian State System utilizes the traditional form of linking—that of cross connecting VHF systems via a UHF intertie. There is another type of interlinking recently developed in a joint venture between the Jet Propulsion Laboratories Amateur Radio Club in Pasadena, California, and the Goldstone Amateur Radio Club near the city of Barstow in California's High Desert. This operation links together two 220-MHz repeaters without using traditional cross-band operation. Common site linking, as it is termed, utilizes no additional spectrum yet affords exactly the same end product as traditional methods. There is only one requirement—the two systems which intend to link must have overlapping coverage.

In this case, such an overlap occurs in the city of Bellflower. See Fig. 43-2. The J.P.L. system, WR6APS, affords solid coverage throughout the greater Los Angeles basin and normally is heard well in Bellflower. However, due to natural terrain, WR6AZN is for the most part, shielded from greater Los Angeles, with only a trace of RF leaking through a break in the natural boundaries that limit its coverage. It is heard in Bellflower, and that is where the linking equipment is situated.

At the home of WB6RFR in Bellflower, a specially modified Midland 13-509 transceiver was installed. Modifications included full duplex capability and CTCS receiver activation. Two separate antennas are used one aimed at each repeater. The most important modification to the basic

13-509 was to give it scanning ability. The linking receiver is switched several times a second to either the AZN output or the APS output. Internal logic is such that when the receiver is listening to the APS output, the link transmitter is ready to talk on the AZN input and vice versa. Normally, it just sits there doing nothing. It cannot be falsely triggered into operation since it requires a specific command to initiate the linking process.

Should a user on either system want to initiate the intertie, he does do by sending a Touchtone command to his own system. This command, in turn, adds a CTCS tone to the repeater output. This is the command tone which the linking package is waiting to see. When it recognizes its command tone it does two things: First, it locks on to whichever channel is transmitting the tone, and then turns on its transmitter. Its transmitter is on the channel opposite the receiver, and thereby accesses the repeater at the other end. If , for example, a WR6APS user initiated the link, then he is being heard on WR6AZN as well. A WR6AZN user, wishing to respond, commands the AZN transmitter to CTCS output. When the APS user drops off, the linking package returns to scan, and now the AZN user can respond. Carrier tails of both systems are short during linking to cause quick dropoff, thereby enabling a quick give-and-take conversation between the two user groups. Once the QSO has ended, the respective systems are commanded back to normal operation for local use.

In the APS/AZN common-site linking arrangement, one finds the normal coverage extension that linking affords, together with an overall saving in spectrum and equipment investment. No extra spectrum is needed, and one receiver and transmitter handle the entire job. The APS/AZN link system has been in operation since early 1978, and has proven to be a very workable alternative to traditional methods in areas where extra spectrum is at a premium.

The easiest, most flexible, but possibly most expensive method to interlink two or more systems is by telephone. Here, one repeater with autopatch facilities simply calls another system so equipped, and the two user groups then operate as one. A good example of this is the many such long-distance links initiated by the Kluge Radio Network(WR5ARL) in Arlington, Texas. Kluge regularly interlinks with autopatch-equipped re-

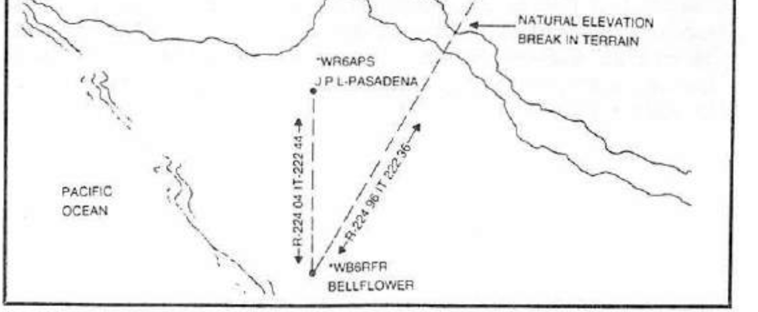


Fig. 43-2. The JPL and Goldstone repeaters are linked on already active repeater pairs.

peaters throughout the nation, and has facilities to tie itself to two other similarly equipped systems at any time. Hearing WR5ARL users on the Los Angeles WA6VQP/R system is quite common, and Kluge members have told me that they find this form of long-distance interaction very stimulating. The only drawback of this method is its overall expense in that one group or the other has to foot the bill for a long-distance call. Other groups have also undertaken this throughout the nation, and the number of limited-time-frame, long-distance ties keeps growing.

We have investigated some ideas on how you can expand the overall utility of your system. There are probably as many other ideas along these lines as there are Amateurs to think of them. We have given you a short list to think about. The others are up to you.

AN AMATEUR RADIO NEWS SERVICE

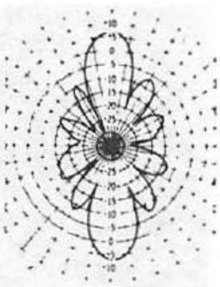
We have already discussed many activities a relay system, particularly those an open FM repeater can be involved in. One aspect not yet taken up is their use as a news outlet, keeping Amateurs informed of matters pertaining to the Amateur service. This idea is not new. In fact, the ARRL has been issuing what they call ARRL Official Bulletins for many years. The League has a complete structure designed to spread such information, and the OBS system has served Amateurs well for years. While the OBS system is quite popular for HF operation, it has never really gathered much support on VHF repeaters.

In the summer of 1977, a young Los Angeles Amateur named Jim Hendershot brought quite a change to the on-the-air Amateur-news QST. He reasoned that such an offering did not have to be dry and in a monotone; the problem often encountered when untrained readers offer such a service. Having had on-the-air broadcasting experience with Christian broadcasting stations in Alaska and the Caribbean, he decided to utilize this expertise to the benefit of Amateur radio, and from this decision was born the Westlink Amateur Radio News.

What's really nice about all this is that it is free. All those involved are dedicated volunteers. The concept is simply that Amateurs have a right to know what's happening in the world around them, and to that end the people of Westlink have dedicated their spare time.

If you are interested in this fascinating concept of Amateur Radio news dissemination, then drop a note and an SASE to Jim Hendershot, Network Director, The Westlink Amateur Radio News Network, 8331 Joan Lane, Canoga Park, California 91302. Now entering its third year, the Westlink News as much a part of today's VHF scene as are FM radios and repeaters. Not bad for a bunch of volunteers.

Chapter 44
User Stations and Equipment



Thus far we have discussed equipment only in relation to the repeater itself. Now, let's get into another area, that of the user station—the equipment that a ham needs to work through local repeaters.

Obviously, you need a radio. The type of radio you select will be based upon many factors, with area activity, cost, and personal taste being but three. However, they should not be the only determining elements, as projected growth in activity is important as well. We will deal with commercially available equipment only, since that is the type of gear that virtually all of today's Amateurs use. Included under this banner is land-mobile FM along with made-for-Amateur equipment.

When the art of repeater communication was new, most Amateurs used surplus land-mobile FM equipment. In some cases, where relay activity was AM, it was converted to that mode with varying degrees of success. As FM took over the scene, many domestic and foreign manufacturers entered the marketplace, and the age of the Amateur FM transceiver was upon us. Today's Amateur has a plethora of equipment from which to choose, ranging from simple, multi-channel, crystal-controlled transecivers and hand-helds to radios which operate "all modes." As this is being written, a new device is being added. I call this the third-generation radio, and it brings with it computer technology and the microprocessor control for added flexibility.

User radios are divided into three basic groups: mobile installations, hand-helds, and base-station units. Under each of these designations one finds three sub-categories which are channelized/crystal control, synthesized, and synthesized/multi-mode. There are no rules as to what must be used where, but common sense dictates that certain designs will have specific uses.

A radio for mobile installation might be anything from a 1950 vintage, one-channel boat anchor to an ultra modern, multi-mode device with microprocessor control. The choice will be dictated primarily by local activity. Actually, this holds true for all types of radio be it mobile, hand-held or base. In the case of mobile operation however, other factors enter the picture. They are the amount of time you spend in your vehicle, the mileage you drive, the esthetics you desire, and the number of bands you operate.

For two meters, the amateur finds the greatest overall equipment selection. See Figs. 44-1 and 44-13. If you live in an area served by one or two repeaters and travel little, then the simplest, least-expensive unit you

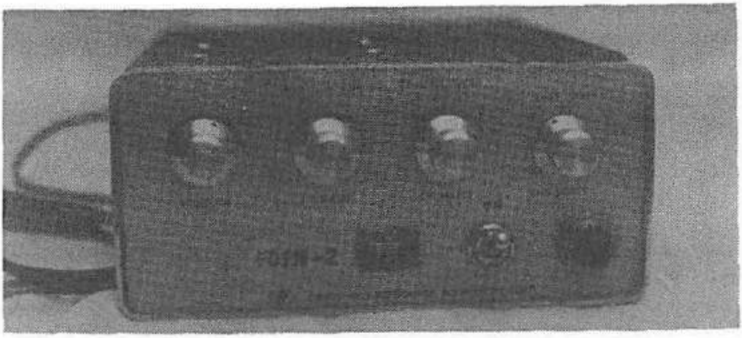


Fig. 44-1. The first imported 2-meter FM transceiver—the FDFM-2 by Inoue Communications, now known as ICOM.

can procure will more than serve your needs. Even if one or two more repeaters come on the air, a six- to twelve-channel crystal-controlled transceiver would fill the bill. The chances of a real boom in area growth is probably slim, and, unless you are interested in modes other than FM, your best bet is to go the simple route. The opposite holds true if you live in an area of high activity. Take Los Angeles for example. From anywhere in this city, the average Amateur can access over a hundred open FM repeaters on two meters alone. Many of us travel between forty and eighty miles to work, and the same distance back home each day. There is not only FM activity, but a growing stream of point-to-point SSB as well. By the time this is written at least one SSB translator will be serving the area and others forthcoming. Spending this much time each day in a vehicle encourages diversity. It is for this reason that most area Amateurs use synthesized FM or multi-mode radios on two meters, and synthesized rigs are big on 220 MHz as well. With the diverse operation in areas such as this, and the desire to use as much of it as he can, the Amateur of this ilk will usually try to get the type of mobile unit which offers him the most versatility and ease of

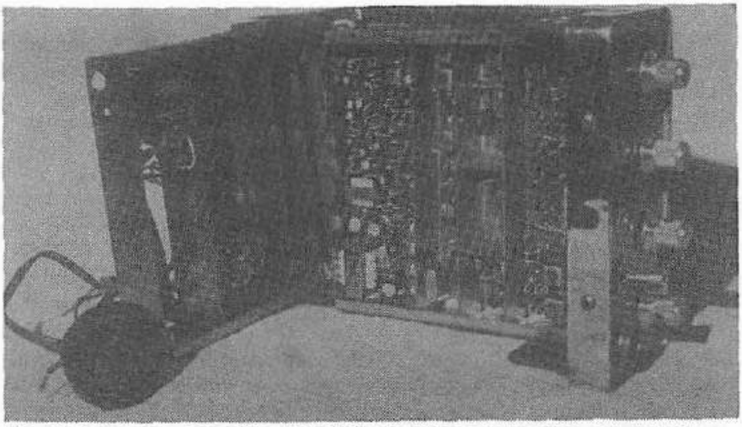


Fig. 44-2. Interior view of the FDFM-2, showing construction and shielding.

operation. Though he is obviously spending quite a bit more than his rural cousin, this expenditure is almost dictated by his choice of residence.

What about the traveling ham? Perhaps he is a salesman who spends much of his time on the road. Then again, his employment may require that he leave his vehicle at home and fly to cities far removed. He, too needs versatility, but with an added factor; portability. Maybe he lives in an area of little activity, but he is never sure what he will find when he arrives at his destination. In the mid 1970s, even his problem was solved when some enterprising manufacturers brought to the Amateur market small mobile transceivers which boasted synthesized operation and moderate transmit power. The traveling ham was quick to realize that such equipment truly

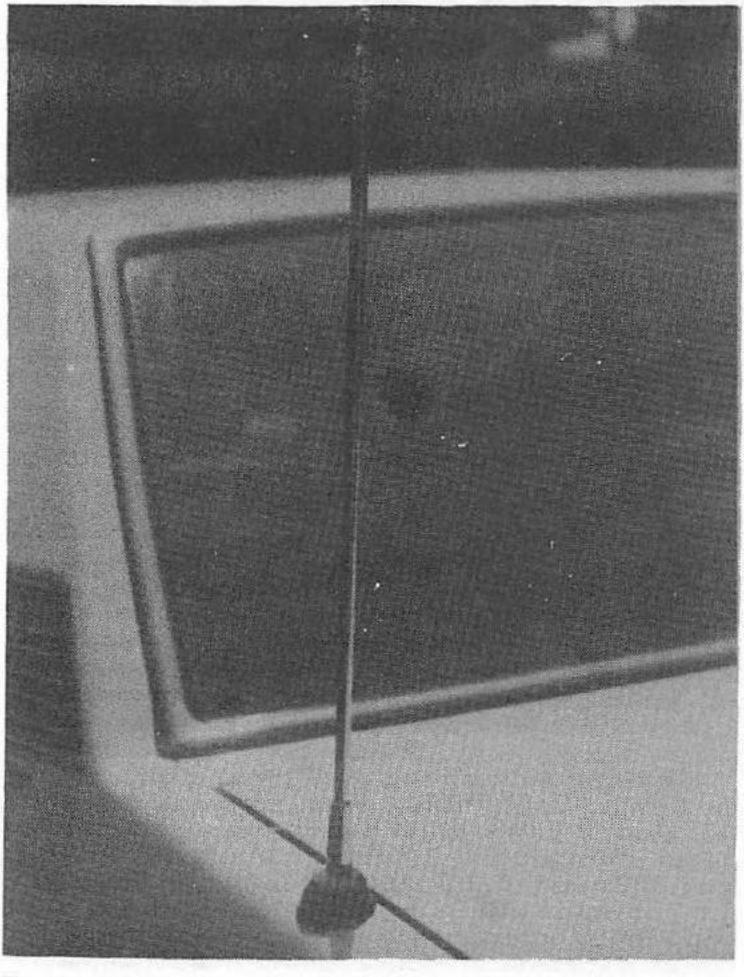


Fig. 44-3. A 2-meter "disguise" whip, designed to appear as a broadcast-band antenna, but works on VHF.

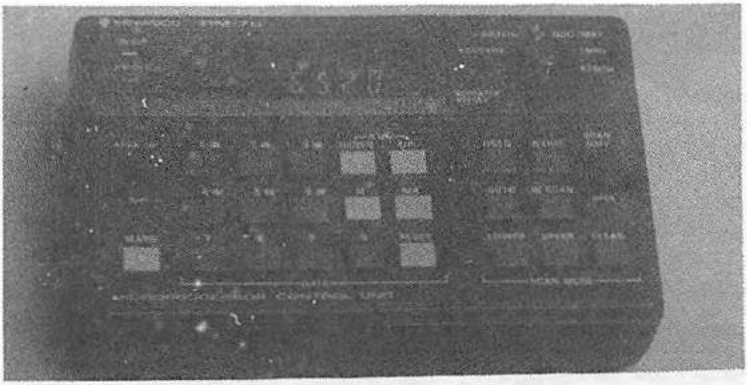


Fig. 44-4. Recent innovations include a microprocessor controller such as this RM-76 (courtesy of Trio Kenwood Communications).

filled his particular need, and today it is not uncommon for him to deplane, hop into a rental car, plug his radio into the cigarette lighter, hang a gutter clip or magnetic mount antenna topside, and drive off, happily chatting away. A small AC power supply lets him convert his mobile to a base radio and he can continue hamming from his hotel room. Though he may or may not use all the features of this radio at home, while away on a trip it is a true blessing. It gives him the best of both worlds.

Esthetics are another factor that enter into any mobile installation. A clean, neat installation is not only pleasing on the eye, but also prevents family squabbles. Because of this, and the fact that the overall size of vehicles is getting smaller as a fuel-conservation measure, the small Amateur transceiver has gained much in popularity. The average radio, be it for 50, 144, 220, or 450 MHz, measures roughly 6"-7" wide, 2"-3" high, and 7"-10" deep. Even the smallest vehicle can accommodate something that size. Blacks and neutral greys are almost standard, and permit equipment to blend with most decors. A variety of mounting equipment is available, and the type of mount you choose will be dictated directly by the interior design of your vehicle.

While on esthetics, let's speak for a moment about antennas. Not too long ago, there was only one way to mount an antenna on a vehicle—cut a hole. With the advent of CB radio, the public demanded that other ways be found that did not require direct modification of the vehicle, and, as a result many forms of clip-on or magnetic-mounting devices were developed. Much of this has been borrowed by Amateurs in their mobile installations, thus permitting "no-holes" installation to become part of the scene. For today's amateur, the most common type of antenna mount is the trunk-lip clip, and is followed closely in popularity by the gutter clip and magnetic mount. While all three do suffice, they have one drawback. None exhibit a truly low-impedance ground return to the vehicle. It is for this reason that many VHF/UHF enthusiasts prefer to forget about a small drop in resale value and cut the necessary holes in a search for maximum performance.

Antennas themselves come in two varieties: unity gain and gain type. The unity-gain antenna is simply a ¼-wave whip, and looks good on almost any vehicle. It has only one drawback: It exhibits a rather high angle of radiation and is a poor choice where the repeater and the user are at about the same elevation. It is also a poor choice if your main interest is point-to-point simplex work, where you want as much RF as possible to hug the ground. For proper operation, the ¼-wave whip, or any mobile antenna, should be mounted in the center of the vehicle's roof, or, if such is not possible due to vehicle design, then the center of the trunk. This is to afford the proper ground plane reference, and effect the best radiation pattern. Best performance will be had by permanently mounting the antenna in the center of the roof.

The "gain" antenna overcomes the problems inherent to the ¼-wave whip, but with a sacrifice in appearance. Gain antennas consist of a coil or impedance-matching device enclosed in a weatherproof housing, and a vertical radiator between ⅝ and ¾ wavelength long for the desired band. Most look like the CB antennas that so many vehicles sport these days. Like their ancestor, the ¼-wave whip, they perform best when installed properly in the center of the roof or trunk lid.

SECURITY

Before closing this subject, let's consider one last topic—that of protecting equipment against theft. Even if you do not live in a high-crime area, there is always the chance of being ripped off and, as you well know, radios are not inexpensive. There are many ways of protecting yourself against theft, but the best solution that anyone has come by thus far is to never leave the radio where it can be taken. Many of today's radios are designed for easy removal so that you can take it with you when you leave the vehicle. Still others offer remote-controllers, like their land-mobile ancestors, which permit out-of-sight mounting of the radio with but a control head and mic in evidence. You can thereby mount the radio in your trunk where it is secure, or at least more secure than in the passenger compartment. Speaking of land-mobile FM, aside from performance, this is another reason why many Amateurs have elected to stay with such equipment. Such radios are very hard to steal, because once installed, they

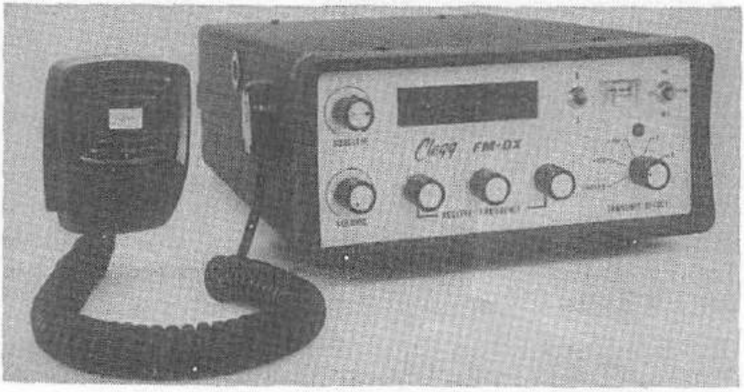


Fig. 44-5. The Clegg FM-DX, a modern, synthesized 2-meter transceiver (courtesy of Clegg Communications).

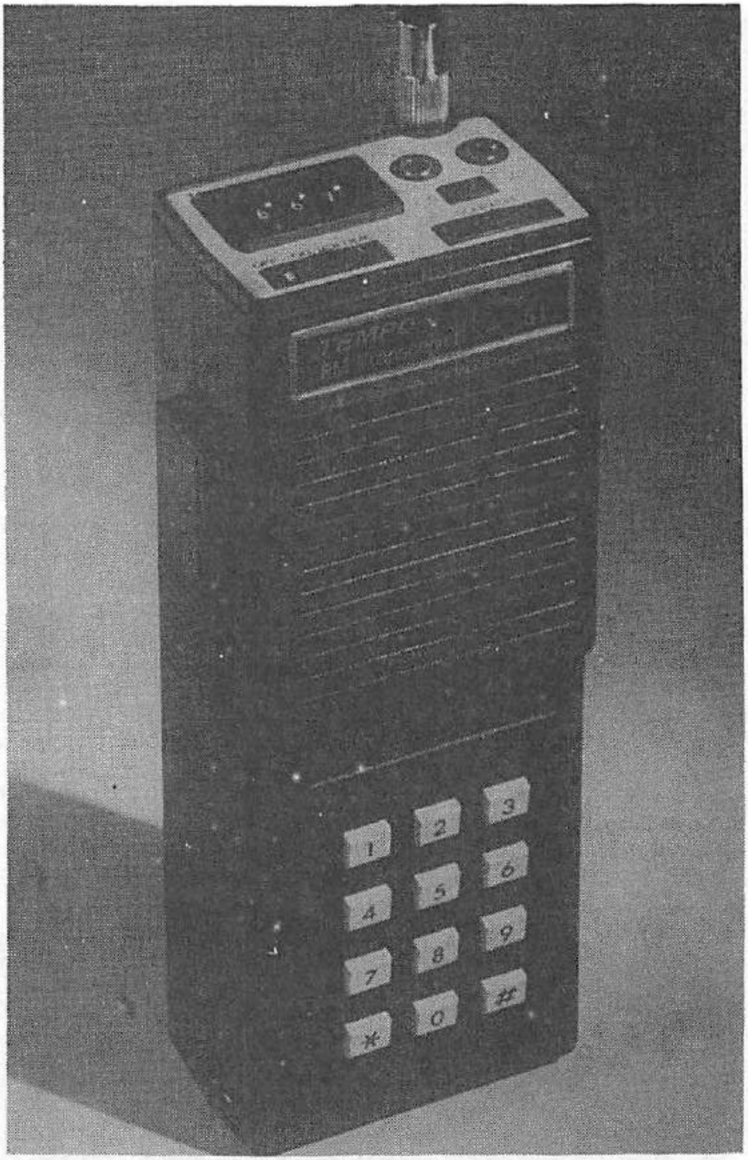


Fig. 44-6. The Tempo Syncom I, a synthesized 2-meter hand-held transceiver (courtesy of Henry Radio).

literally become part of the vehicle. Virtually all require a special key to remove the radio for service, and the locks these keys fit are tamper proof. The big drawback of even the most modern of these radios is channel capability. They were not intended for Amateur service and require exten-

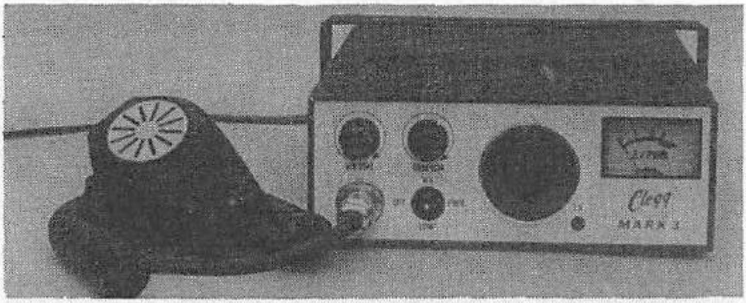


Fig. 44-7. If there are few repeaters in your area, then a 12-channel radio will suffice (photo courtesy Clegg Communications).

sive modification for more than two- or three-channel operation. To overcome this one handicap, Amateurs in high-activity areas often modify them to accept frequency control from an outside source such as a synthesizer. Unless you are a true home-brewer with a good sized junk-box, such items as synthesizers cost almost as much as some radios, and, if left in the passenger compartment, they run the same risk of theft that any radio would. Therefore, unless area activity only requires a few channels on which the radio must perform, and the user is satisfied with this limitation, for the average ham it will be self defeating. Finally there is initial cost. Even used, land-mobile FM equipment of modern design is not cheap. We are speaking of equipment designed within the last ten years, not the battery hogs of the 1950s. A good, all-solid-state radio which costs $2000 to $3000 new will retain at least half that value after five years. Even some early tube/transistor hybrid equipment still brings a handsome penny. True, this equipment is far more rugged than that which is built for amateur use, no one will deny this. By far, the land-mobile FM radio is the most theft-proof in design, but offers the least in versatility to the two-meter FM operator.

UHF ACTIVITY

There is one band where the land-mobile FM radio is still king, and shows little sign of loosing popularity—probably due to the lack of Amateur

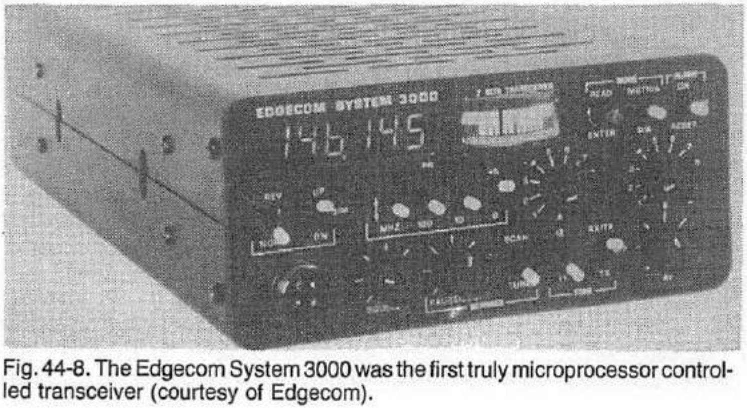


Fig. 44-8. The Edgecom System 3000 was the first truly microprocessor controlled transceiver (courtesy of Edgecom).

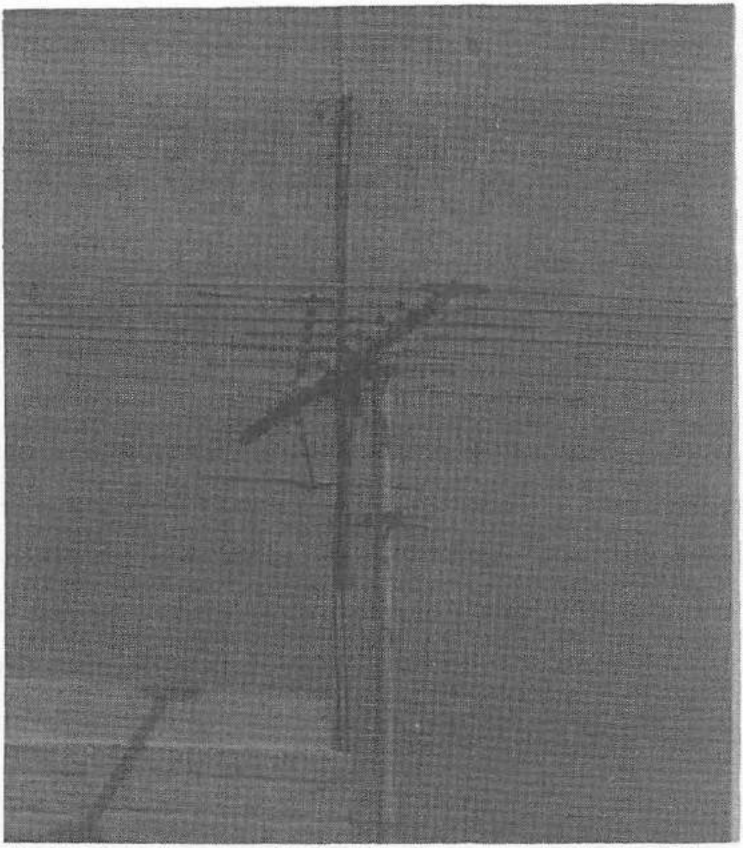


Fig. 44-9. A simple way to add a 2-meter antenna—mount a Cushcraft Ringo above your TV array.

equipment for the spectrum. I speak of 420 to 450 MHz; and, while we are at it, I might include the 50-MHz band to a lesser degree. 420 to 450 is not a transient band. That is to say, one does not find Amateurs wandering town to town looking QSOs in the same way as on two meters. The users of this spectrum tend to group together either in clubs or special-interest groups, and repeater activity tends to reflect this. Many of the current 450 inhabitants are ex two-meter types who looked for less crowded, "greener pastures" upon which to continue their experimentation. Others simply moved there because the type of activity they were involved in required a more controlled environment than could be had on two meters. In many areas, virtually all repeater activity is tone-access, and considered closed or private in nature. This, combined with the ongoing East-West feud over bandplans, has tended to keep activity level lower than on two meters.

Most amateurs involved in UHF repeater operations use land-mobile FM equipment of as modern design as can be procured. Such radios might not meet activity requirements for two meters, but the one or two channels they offer are usually sufficient for the 450 MHz enthusiast. Since many UHF systems are advanced-format operations, a single-channel radio can serve for operation on many bands, through the proper links. Perhaps this is the reason that few Amateur-equipment manufacturers have ventured into this market, and those who have offer only simple, multi-channel crystal-controlled rigs at this time. There is one synthesized radio capable of 450 operations: the Drake UV-3. However, this radio is a three-band unit which covers 144-148 MHz, 220-225 MHz, as well as the 450 band. It is too early to say what effect the UV-3 will have on 450 activity. For the moment, equipment manufactured by Motorola, General Electric, and other land-mobile FM manufacturers reigns supreme on the 450 band.

6 METERS

What about six meters? Much of what has been said about 450 also holds true for six. There have been, and still are, a number of Amateur transceivers marketed for 50-MHz FM. Regency was among the first to have such a unit and, though they no longer produce Amateur equipment, many of their six meter transceivers are still in use. Genave and others have marketed multi-channel crystal-controlled radios, and KDK has one which is synthesized. Unfortunately, there is still no national agreement on repeater sub-band utilization or repeater input-output offsets, and this has impeded the flow of new second and third generation equipment. Once Amateurs do agree on how to utilize the six-meter sub-band on a national basis, expect it to take off, perhaps becoming another "two meters."

Presently, equipment used on six meter FM seems to be a 60-40 split, with commercial land mobile FM equipment still favored over Amateur equipment, but the latter is making deeper inroads as time progresses.

10 METERS

This leaves us only with 10 meters, and here again, one finds a mixture of land-mobile FM, Amateur and some extensively modified CB equipment. By far, land-mobile FM is the predominant equipment in use.

Hand-held transceivers for both ten and six meters do exist, but are far from common. There are none designed exclusively for Amateurs, so we

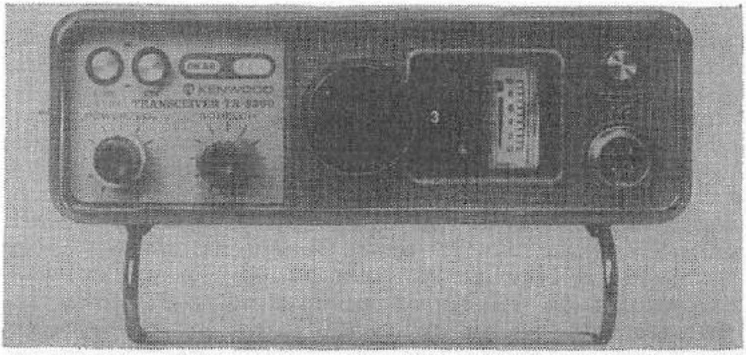


Fig. 44-10. A neat 12-channel transceiver for the 420-450 MHz band (courtesy of Trio Kenwood Communications).

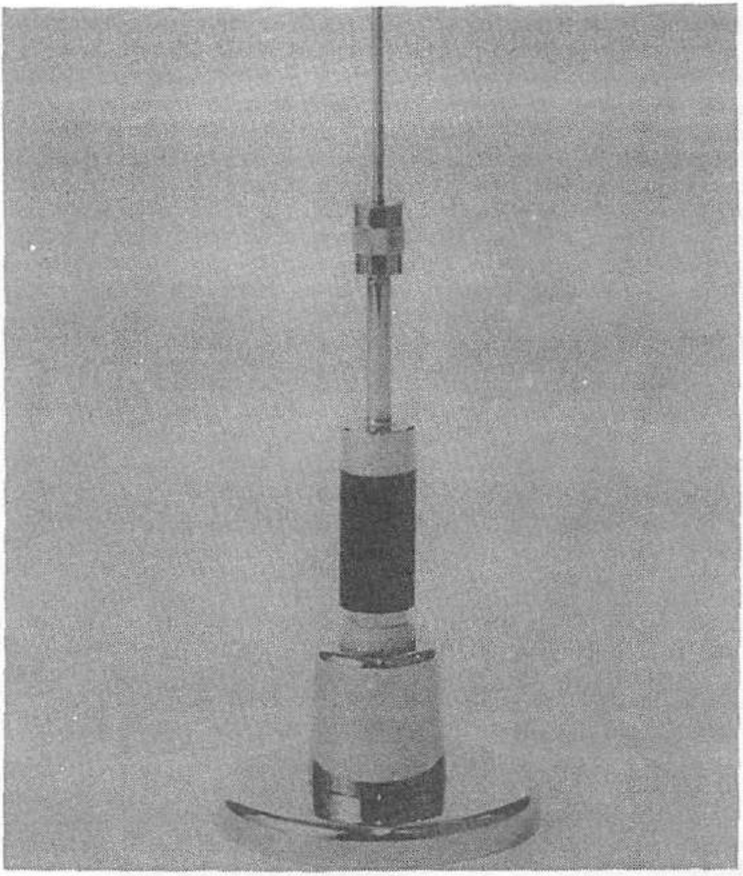


Fig. 44-11. Magnet-mount antennas make installation on a vehicle quick and easy (courtesy of Cushcraft).

must resort again to land-mobile FM as a source of supply, and, even used, such items are fairly expensive. As with mobile transceivers, hand-helds fall into three categories here too. Land-mobile units, especially the Motorola HT-220, are extremely popular in many Amateur circles. But as with all such equipment, extensive modification is necessary to place it into Amateur service. Unlike mobile equipment, the complexity and small size of these units dictates that only those with true expertise attempt such conversions. For one's efforts, he will have a one- to six-channel hand-held with up to 7 watts of transmit power and extremely rugged design. These units are designed to take abuse and keep on working. Your cost for such a unit, figuring purchase of a used but operable unit and all parts necessary for conversion, can range anywhere from $200 to $600 or more—depending upon the band it operates on, the accessories that come with it, and it's popularity in your area.

AMATEUR HAND-HELDS

As early as 1970, there were on the market hand-held transceivers designed specifically for the two-meter ham. Overall designs did not change much for many years, with the chief parts of the evolution being smaller size and better receiver selectivity. All were 5- to 6-channel crystal-controlled units, with between one and five watts transmit power. They were powered by conventional size AA Nickel-Cadimum rechargeable batteries. Their commercial cousins also used Ni-Cad power. However, batteries for such units are of special design with a much higher price tag. Most manufacturers had as options only charging units and carrying cases in the beginning. Such amenities as twelve or sixteen button auto-patch encoders were added to the list later on. Today, a high-quality transceiver of this type, with all options costs about $300 new, average price, and offers operational quality comparable to its commercial-service cousin.

In early 1979, a new type of hand-held came on the scene. It offered all of the features of its predecessor plus one many Amateurs had thought impossible. Full frequency synthesis over the entire 144- to 148-MHz band, and in a package small enough to fit in a jacket pocket. The first unit of that type on the market was the Tempo S1 Syncom, with an advertised price of under $350 including batteries and charger. Since then, other manufacturers have announced similar units, and the once popular crystal-controlled, hand-held is fast giving way to a second generation device.

There has been only one 220-MHz hand-held offered: The model 2202 by Wilson Electronics. This unit was discontinued in late 1978, and thus far no other manufacturer has seen fit to enter this market. Since it is nearly impossible to successfully convert any land-mobile equipment to this spectrum unless one is a true expert in the communications-design field, the Wilson 220 hand-held is a sought after radio in many places, and brings top resale dollar.

Again, when it somes to 450-MHz operation, amateur transceivers take a back seat to commercial land-mobile equipment, and the Motorola HT-220 is by far the most popular hand-held among UHF FM enthusiasts. It is probably the most sought after piece of equipment, and has been for many years. Some Amateurs have been known to actually purchase these units new, which was quite a big investment. The HT-220 has become somewhat of a status symbol, and a standard to which every other piece of equipment is compared. Nowhere in the long history of amateur radio has a

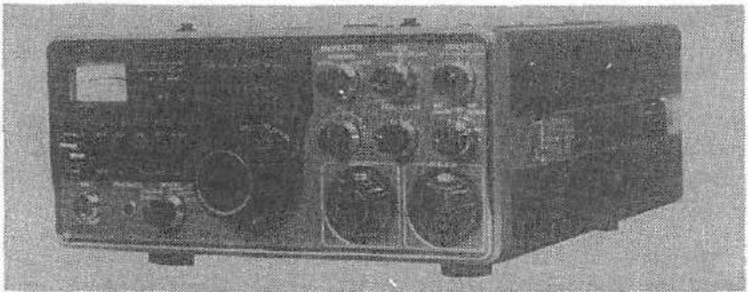


Fig. 44-12. An all-mode transceiver for 2-meters (courtesy of Trio Kenwood Communications).

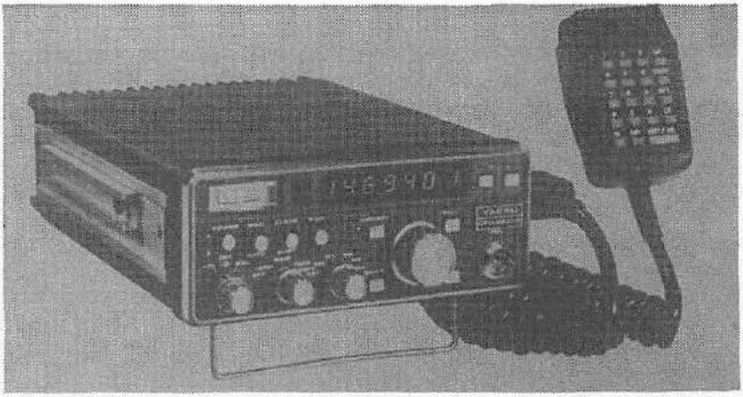


Fig. 44-13. A 4th generation radio from Yaesu—it's microprocessor controlled (courtesy of Yaesu Electronics).

piece of equipment designed for another service had such a profound impact on Amateur communications as has the Motorola HT-220.

What makes this even more interesting is that there are other handhelds—both land-mobile FM converted to Amateur service, and units designed specifically for Amateur 450 operation available. They offer similar specifications and comparable performance. Yet the HT-220 seems to have no peer in the world of Amateur UHF FM communications.

Options for hand helds are few: Battery chargers, spare battery packs, carrying cases, helical antennas, and tone encoders for autopatch use just about cover the list. These, along with crystals, make up the entire package and affords today's Amateur with the most flexibility and portability he has ever known.

BASE STATIONS

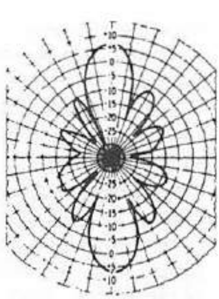
One probably finds the most diversity in base-station installations. For many Amateurs, his mobile transceiver is made to do double duty by connecting it to a regulated power supply and external antenna. This holds true for both two meters and 220 MHz. The only added cost is that of a power supply, antenna, and transmission line.

There is another type of radio available for base-station use. It is known as the multi-mode, radio and several manufacturers offer models for both the six-meter and the two-meter band. They are single-band units, which gives the operator the greatest flexibility for the band he chooses. In an attractive package, which resembles an Amateur HF transceiver, is found a radio that will permit operation of SSB, CW, AM, FM and FSK with digital frequency readout as part of the package. While far more expensive than FM-only transceivers, they offer the serious VHF enthusiast the most advanced and versatile piece of equipment available today.

There are no such rigs yet available for either 220 or 450 MHz. Operations on 220 MHz are usually mobile transceivers and external power supplies, while on 450 MHz it's generally the land-mobile base-station radio in evidence. Above 450 MHz, the word is home brew and Amateurs, regardless of their mode or special interest, do go that route.

Chapter 45

To The Future—Computerized Repeaters



When I first outlined this book, I had thought in terms of including a complete microprocesser based repeater controller. Microprocessers are truly amazing devices, and it seemed appropos, until it was pointed out to me that microprocessor and micro-computer technology is moving ahead at such a rapid pace, that the material could easily be outdated by the time this reaches print, and that the specialized chips that would be contained in such a work might not be available in a few short years; superceded by something better, but totally incompatible with what we would present. Therefore, in June of 1978, this idea was scrubbed, and a totally different approach was initiated. Enter Larry Levy, WA2INM.

The friendship between Larry Levy and Bill Pasternak goes back to the fall of 1959. Newly licensed, I had just completed my very first homebrew rig—a complete, 25-watt transmitter and A-M modulator, built from the remnants of a DuMont RA-109 Television receiver. Six meters was the game, and to complete the lineup, I had procured a Heathkit AR-2 receiver and an L&W converter. All this fed an indoor wire dipole, since I was forbidden any outside antenna system. Within the first few days of operation, I had worked WA2INM many times. Even back then, six was not the most populous band, and frequent QSOs with the same bunch of stations was quite commonplace; somewhat akin to the repeater of today, but without the range and exotic hardware. Somehow, an instant rapport developed between these two teenage hams, which developed into a tight friendship that has withstood the test of time.

As you may have surmised, like myself, Larry hails from Brooklyn, New York. He is about three years my junior, and attended Brooklyn Academy High prior to enrolling in Marlboro College, Vermont, where he majored in Electronics and Electronic Engineering. While in College, he became interested in the basic concepts of computers and their everyday applications. Out of this grew a business known as Mind Garden Electronics, which designed and built automated and audio-actuated lighting displays for the early Discos of the late 1960s. As the first phase of the Rock Disco scene faded, Larry turned his attention to other endeavors, and the result was a three year partnership between the two of us in a consumer electronic service business. Even while we worked together at the mundame task of making a living, Larry's mind and heart were always wandering hither and yon. He spent much of his spare time refining his computerized lighting techniques, and while our main livliehood came from repairing television receivers, we managed to keep in the "show-biz" electronics scene with a number of special presentations for the United Nations, the Friar's Club, and the famed Fifth Dimension vocal group.

In September of 1972, I turned the reins of our business over to Larry and relocated to Southern California. Shortly thereafter, Larry developed an almost insatiable interest in the concept of computerization, which developed into a fast growing business known as Computer Emporium, located in the heart of New York City. Larry is as adept in building a computer as he is a repeater, or any electronic device. If he needs something special, he will design and build it himself, be it an analog, digital, or linear device. Since 1960, he has written for *73 Magazine* on various subjects, and along with myself and the Kings County Repeater Association of Brooklyn, N.Y., was responsible for the nation's first successfull split-split 15-kHz tertiary channel repeater. Most of all, he, too, has the ability to dream. To think the impossible and make it come true. That, above all else, is why it is truly appropos to have Larry as a part of this book, and moreover as your guide into what the future may hold in store.

COMPUTERIZED REPEATERS

With the microprocessor being as common and cheap as it currently is, it is surprising that more applications in the field of Amateur Radio are not evident. Perhaps it is a sign of the times that Amateurs are not even remotely as close to the threshold of communications technology as they used to be. In all fairness, there is somewhat more to know these days, but that is not a good excuse for amateur radio as a whole. Digital communications is a whole new area that had hardly been approached by amateurs, with the possible exception of a few TTY addicts using obselete 1938 Baudot teletypes with relay and mechanical logic. We did not scream because the FCC did not allow us the almost world wide standard ASCII, which has been in commercial use since the early 1960s, and as a result, we have been forced back to the dark ages. We should have been using it before most of the commercial users. Most hams don't even know what ASCII is, although it is now legal on the ham bands.

Commercial data communications have progressed a fantastic amount using digital multi-channel communications capability at a much higher rate than speech, Morse, or Baudot TTY, and over fairly narrow bandwidth phone lines and radio links. All with parity , error checking and recovery, and many advanced techniques that Amateurs, who are supposed to be communications and radio specialists, have never heard of. We, the pioneers of the communications field, who "pound the brass," using technology that is essentially the same as what was in use in the earlier part of the century. I must admit that there are many refinements, but the basic concepts of communications technology are as up to date as the De Forest valve and the telegraph. And about as efficient.

It seems likely that, at some point, we will be forced to improve our communications as the bands get more crowded and we have less and less spectrum to play with.

The microprocessor is going to change our concepts of communications far more than voice communicatons and the vacum tube changed the old spark-gap standard. We must start learning about them now so that we will understand what is happening five years from now. In a few years, there will probably be very few stations or repeaters that will not be microprocessor based. We are going to have to learn about some hardware and software to survive. See Figs. 45-1 through 45-3.

The repeaters of the near future may or may not all have voice communications capability. They will have a microprocessor for all control functions, and either a floppy or hard disk for programs and storage (logging information, messages between users, ets.) plus a reasonable amount of memory. You will access the repeater with a digital access code which may be as simple as your call (if the computer does not have your call on the list of users it will not allow you to use the machine) plus possibly a password, or as complex as, for example, the CRC * of the current time/date/and an arbitrary 64 digit number. Once you are logged on, the computer may give you any messages on the disk that have been left for you since you last logged on, and then you may call or communicate with another station. Some of the larger repeater groups may turn the repeater into a community timeshare computer with capabilities that would be too expensive for most of the individual users. Links to satellite communications may not be uncommon either. Satellite communications should probably be handled by computer most of the time. You would store the transmission on a disk and send it at very high speed when the time and position was right, and receive replies the same way. This may allow thousands of times more contacts to take place in the limited time window of the satellite than would be possible using present methods. The repeater's disks could store transmissions and replies for many users who may not be on the air at the optimum time for the satellite window. The computer would also be able to control antenna tracking and timing. Most voice and mobile communications through re-

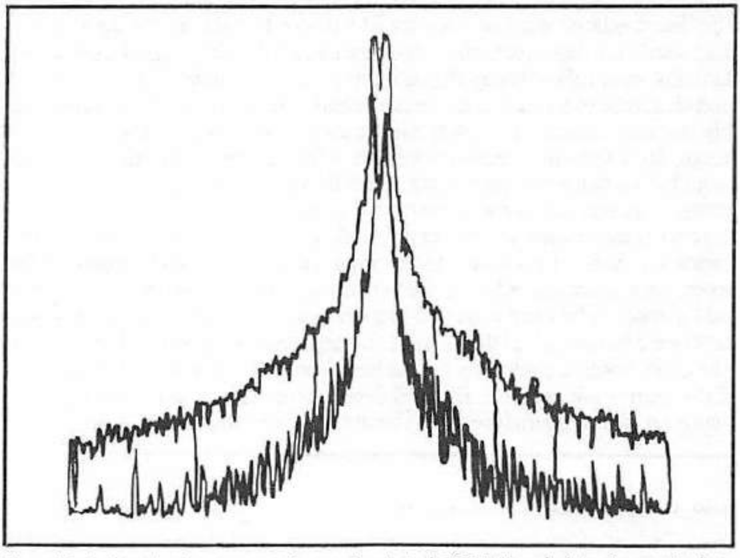


Fig. 45-1. Spectral response from simulated 1200 Baud data transmission. Deviation was 0.5 kHz.

peaters would still be computer controlled, with each rig automatically sending the digital ID with each transmission, allowing the computer to log all transmissions. A simple ROM* based encoder will probably be standard in all rigs, and will transmit the ID each time the PTT button is pressed. This will also make it hard to steal a rig or to bootleg.

*CRC: "Cyclic Redundancy Check"- A technique of error detection, too complex to explain here, but used here as an easy-to-generate (with hardware), but difficult to "Break" (by unathorized personnel) entry code.

As I mentioned before, we should start thinking now about digital standards and conventions. I would like to propose a few ideas as a starting point. We will have to standardize such things such as transmission speed, signal conventions, methods of encoding, number of start, stop, and data bits, etc. A reasonable starting point may be 1 start bit, 8 data bits, and 1 stop bit, with either 1200 or 2400 baud rate. I would also like to suggest a possible method of digital transmission that is cheap, simple, and easily standardized and could be added to existing equipment with an absolute minimum of problems. It does not require modems, terminal units, or anything more than a couple of 29 cent chips and a few minutes of work. If you take the serial output of a normal RS-232* port and pad the voltage correctly, you should be able to connect this voltage to a reactance (varractor) modulator, and create a very precise and predictable frequency shift for a 1 or a 0. It would be reasonable to assume a +0.5 kHz offset for a 1 and a −.5 kHz offset for a 0. An additional advantage to this technique is that when the carrier is on channel, the receiving computer "knows" that data is not being sent. A small capacitor across the output would keep the slew rate down to a figure that would allow 1200 or 2400 baud data to be transmitted with a bandwidth that would not exceed a 3 kHz or so deviation voice channel. Recovery of the data would require only a simple comparator at the discriminator, plus perhaps an EIA driver to convert the data back to EIA levels for those units that could not use a TTL-level signal. A standard like this would allow cheap digital interface to communications equipment, and should be extremely noise immune and reliable. It would allow reasonably fast communications (2400 baud is about 240 characters per second or about 40 words per second) over crowded channels. Another area that would allow much improvement is error detection and recovery. There are many common, and some uncommon, methods in use to detect and even correct transmission errors. One simple method is parity checking. This sends an extra bit position and the total number of 1 bits is either odd or even, depending upon the convention in use. If the correct character has an odd number of bits and you are using even parity conventions, the extra bit position contains a 1. If the correct character has an even number of 1 bits, the extra position contains a 0. The hardware will check and report an error if the sum is not correct. This will detect some errors, although a 2 bit or more error may go undetected. There are more complex (for a person, not

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*ROM: A standard abbreviation for "Read-only Memory".

*RS232: The Electronic Industries Association has a set of standards, one of which is a standard for serial data transmission. For the purposes of this discussion, we will limit the explanation to the fact that the 1-0 states are equivalent to a plus and minus voltage.

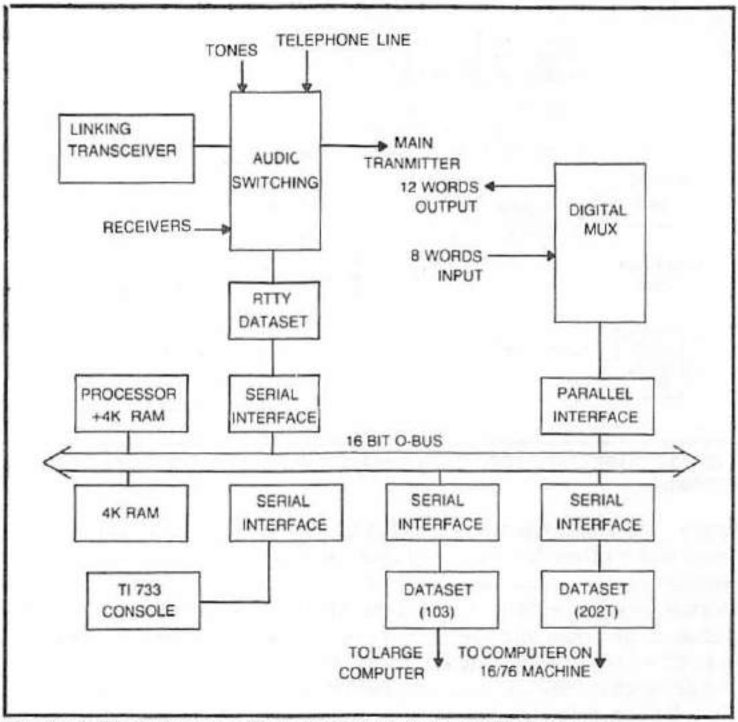


Fig. 45-2. Block diagram of a microprocessor controlled repeater.

a computer) methods of error detection and recovery that are used. One of these is called, interestingly enough, Hamming codes. This is an extra character, sent every 8 or so characters, which contains data that the computer can use to check the last *n* characters and can correct automatically any single bit error, and will detect and report any errors that are larger than it can correct.

There are many interesting possibilities that will be fun, and add an entire new dimension to amateur radio. Contests will be different, with the computer doing all the logging, point checking, duplication checking, etc. A station would be able to operate completely under software control, and not need human intervention. This could allow messages to be left and acknowledged over a local repeater while the operator is not present, among other uses. This technique of message handling is called "store and forward". It has been in use commercially for years. There are some fantastic games that could be developed and played over the repeater, and for those who are into traffic nets, the possibilities are incredible.

Whether or not we like it, we are going to be forced to learn and use these methods soon, so we might as well start now and be prepared. We no longer have a choice... WA2INM.

What you are reading here is finished text. Edited, corrected, and polished for publication. You, will never get to see original manuscript, and therefore are not aware of how it may have been put together. In most

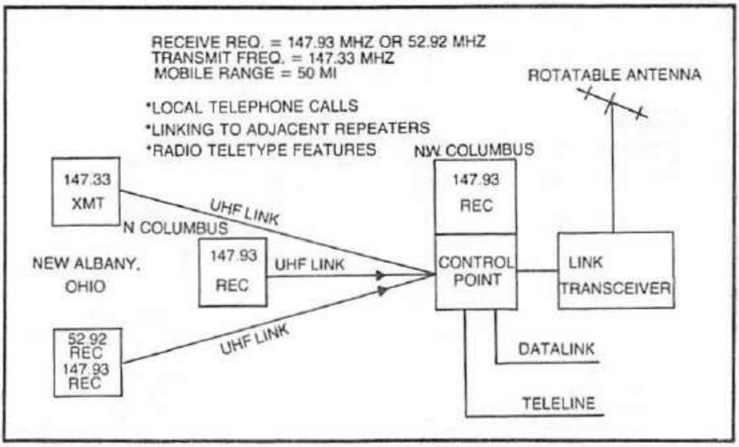


Fig. 45-3. System coverage and connections for the microprocessor controlled repeater.

cases, it is simply typewritten on 8½ x 11 inch paper. Virtually this entire book was written that way. However, one exception does exist: As if to emphasize what he has said in the preceding pages, Larry did not use the normal means of writing. Instead, he wrote the original text onto a CRT terminal, and then into the memory of his own computer. He then performed his own text editing, and only after he was satisfied with the results did he punch in the magic code that permitted the computer to type the final draft for him. It is perfectly typed on normal sized paper. Yes, Larry's text on computers in relation to amateur relay devices was written on a computer.

TEST RESULTS WITH THE WA2INM DIRECT DATA TRANSFER SYSTEM

Question: Does Larry Levy's "Direct Data Transfer" work? To find out, our Technical Advisor, Mike Morris, WA6ILQ, performed some lab experiments to see for himself. Using a square wave audio generator to simulate 1200 Baud he experimented with different deviation levels until he found that 0.5 kHz deviation would produce the spectrum pattern shown in the photo, Fig. 46-1. Judging by it, Larry is correct and such direct data transfer is possible.

In discussing Mike's findings, Larry suggested that "playing games" with the slew rate of the data might permit use of even greater deviation factors while still maintaining the overall integrety of the concept itself, in effect, obtaining a better signal-to-noise ratio at the receiving end. Based upon this, it is our conclusion that the WA2INM "Direct Data Transfer" method described in his text holds merit for future Amateur "computer-to-computer" communication, and is a system that Amateurs should look toward developing for the days to come.

The Canadians have already acted by creating a "Packet Radio" subservice within the structure of the Canadian Amateur Service. Hopefully, we may soon follow their lead and thereby open to U.S. Amateurs a truly new frontier in communications.

Larry has just given you a glimpse into the future, the possible world of tomorrow. What about today? How are microprocessors being used in today's repeater systems? An excellent example of what is possible when a computer is tied to a repeater can be shown by looking at what has been accomplished by Jim Azbell, WB8SYK, and the Central Ohio Repeater Club with their 147.93/.33 system. It's an interesting story, and Jim has provided the following data.

Why Computer Control?

- TO INCREASE FLEXIBILITY
- TO PROVIDE MORE SOPHISTICATED CONTROL

Advantages:

- MINIMIZES COMPLEX HARDWARE
- SIMPLIFIES CHANGING AND EXPANDING THE SYSTEM
- GREATLY SIMPLIFIES DIFFICULT CONTROL PROBLEMS

Disadvantages:

- MORE COSTLY
- REQUIRES "PROGRAMMING"
- A SINGLE FAILURE USUALLY CAUSES COMPLETE SHUTDOWN

PROCESSOR-CONTROLLED REPEATER

Features:

- STANDARD VOICE OPERATION - TIMERS ETC.
- CW ID AND CW TIME AND DATE
- AUTOPATCH WITH ABBREVIATED DIALING AND AUTOMATIC LOGGING CONTROL WITH CW TIME
- AUTOMATIC SWITCHOVER TO RTTY MODE AT ANY TIME
- COMMAND STRUCTURE IN RTTY MODE WITH FULL-DUPLEX
- LINKING CAPABILITY TO LARGER COMPUTER FOR GAMES ETC.

Non-Repeater Features:

- DYNAMIC MEMORY DISPLAY
- REMOTE CONTROL OF SYNTHESIZED TRANSCEIVER
- GATHER ACTIVITY DATA ON AREA REPEATERS

Features Implemented By Computer

- COMPLETE AMATEUR RADIO REPEATER FUNCTIONS
- MULTIPLE RECEIVER MANAGEMENT
- TOUCH-TONE COMMAND STRUCTURE

- STORE AND FORWARD OPERATION ON TELEPHONE NUMBERS, INCLUDING ABBREVIATED DIALING
- MULTI-PORT, MULTI-CHARACTER-SET COMMUNICATIONS
- TERMINAL COMMUNICATIONS COMMAND STRUCTURE
- FULL CONTROL OF A SYNTHESIZED TRANSCEIVER AND ANTENNA FOR LINKING TO OTHER FREQUENCIES
- RADIO DATA LINK TO A SECOND COMPUTER-CONTROLLED REPEATER

This repeater contains a comprehensive set of Teletype features not usually found in a communications-only machine. Most of the advanced operation is easily achieved using the 6-meter input on 52.92 MHz. The full duplex user may transmit on 52.92 MHz and receive on 147.33 MHz simultaneously. The Teletype keyboard is connected in this case to the transmit-tone generator with no connection to the printer discriminator circuit. The user receives his own typing through the repeater. The advantage of full duplex operation is that the user may issue directives to the repeater and receive printed output immediately. This is sometimes considered "interactive operation."

The normal tone frequencies utilized on the repeater are 2125 Hz mark and 2975 Hz space, with 5-bit start-stop baudot code at 60 WPM speed. (167 MS per character) the user's FM transmitter should be modulated at about 4kHz deviation with the above tones. The same tones are used on the repeater output. Tone and coding options are available for narrow shift, "103 Dataset" tones, high-speed, and ASCII coding.

When this repeater is in teletype mode the input characters are deserialized, buffered then resent on the repeater output. Also the timeout timer is disabled as long as characters are being received. If teletype signals are sent when the repeater is not in RTTY mode, the audio signals are repeated in the same manner as voice but the timeout timer will turn off the transmitter in 3 minutes as usual and the teletype characters are not being regenerated.

The RTTY mode is entered when the repeater receiver detects the "mark" tone during the 4 second initial delay period from a cold start. Once the repeater is made "active" (after 4 seconds of carrier) and is in the teletype mode it remains so until the receiver fails to receive an input carrier for about 3 seconds. At this time the repeater reverts to normal voice mode and the transmitter shuts down.

For communications purposes no special operations are required. All input typed on the input frequency is repeated on the output frequency. The special features of the repeater utilize a command structure based on directive names preceeded by two dollar signs. ($$) all the directives to the repeater have the form:

Command ARG CR

Where command is one of the system directive names, ARG is an optional argument needed for some directives and CR is carriage return. The repeater will automatically supply a line feed after carriage return when a directive is issued. This is not the case for normal communications.

The following directives are valid currently:

$$Time HH:MM MO/DA

This directive reads or sets the internally kept time and date for the repeater. If no arguments are supplied the time will be returned as currently set. The time argument and/or date argument may be present and the corresponding value will be set. HH is hours (24 hour time); MM is minutes; MO is month (1 to 12) and DA is day of month (1 to 31).

$$Help

This directive prints a brief repeater description and a list of additional directives for further information.

$$Ttymodes

This directive prints details of the teletype coding and speed options.

$$Ttcodes

This directive prints a complete list of all valid touch-tone codes for the repeater.

$$Autopatch

This directive prints a description of the autopatch facilities of this repeater.

$$Basic and $$Games

This directive connects the full duplex user to the large computer and sets up to run basic programs. Give the directive $$Games for details on running the basic system.

$$Membership and $$Memsys

This directive connects the full duplex user to the large computer and sets up to run the membership maintenance programs. Give the directive $$Memsys for details on running the membership system.

$$Linkr

This directive describes operation of the "linking" features of this repeater. These features are implemented with touch-tone digits.

$$Aptable ET All

The directives $$aptable, $$aptablemod, $$aptableadd and $$aptablerem are used in conjunction with the user provided abbreviated dialing system. Give the directive $$apads for a full description of this feature.

$$Freqreport

This directive prints a list of channel activity on selected repeater output frequencies. This constitutes a usage monitor for the channels. This is central Ohio's most complex repeater. It is owned and operated by the Central Ohio Radio Club Inc. and provides the following features for radio amateurs:

- Standard voice communications
- Open, easy to use autopatch with full duplex and abbreviated dialing capability
- Open linking capability to other 2M frequencies allowing users to access somewhat distant repeaters or simplex frequencies with hand held units.
- Half duplex teletype communications at 60 WPM baudot code
- Full duplex teletype operations including access to a computer for playing computer games and accessing the membership records.

Input to the repeater is on 147.93 MHz or 52.92 and the output is on 147.33 MHz. No special tones are needed but an initial carrier interval of 4 seconds is required from a cold startup. For details on the autopatch give the command $$Autopatch. For details on the linking capability enter the command $$Link. For details on the teletype features enter the command $$Teletype. For latest update on repeater features enter the command $$News.

The repeater teletype functions can be operated in a number of Modes regarding speed, coding and tones used. The following table lists the modes available:

Function	Default	Available
Tones	2125 mark 2975 space	Narrow shift 2125 mark 2295 space "103 Dataset" tones 1270 Mark Receive 1070 Space Receive 2225 Mark Trans 2025 Space trans
Coding	Baudot	
Speed	60 WPM (Baudot) 110BPS (ASCII)	ASCII Fast speed (100WPM) (300BPS)

Note: On narrow shift operation the repeater is expecting wide shift on the input at all times. The narrow operation applies to the transmitted AFSK signal only.

When the repeater drops the transmit carrier after teletype operation, all of the options revert to the default case. Also if the reset touch-tone code "813" is sent, all of the options revert to the default case. There is a set of command directives to switch on the options. Obviously this is of limited use since a user with an ASCII machine for instance cannot give the command $$ASCII in the default baudot code. Therefore there are a series of corresponding touch-tone codes that will "prime" the repeater to expect teletype operation with the desired options turned on. Any number or combination of these codes may be entered prior to teletype operation enabling any of the options. Just recall that teletype operation requires that AFSK mark tone be present during the inital 4-second interval after the repeater has dropped its transmit carrier and that touch-tone sequences must be terminated with drop of input carrier or the digit "pound-sign".

The following table lists the options, the command directives, and the corresponding touch-tone code.

Option	Directive	TT-Code
Narrow shift (transmit only)	$$Narrow	833
Fast speed (100 WPM or 3ff BPS)	$$Fast	834
ASCII Coding	$$ASCII	835
"103 Dataset" Tones	$$103	836

Actually this option switching is rather complex and difficult.

The autopatch on this repeater contains a feature providing users modifiable abbreviated dialing tables. The abbreciated dialing touch-tone code is "STARXX" where XX is a two digit code referencing an entry in the abbreviated dialing table. XX may range from 01 to 99 inclusive. Emergency numbers are on a separate list, start with "1" and have 3 total digits: "STAR 1XX".

A user may examine the table of telephone numbers and their codes on teletype with the command "$$APTABLE". A listing of the currently defined codes and the corresponidng telephone number will be printed. A new code may be added with the command "$$APTABLEADD XX, NNNNNNN" where X is the abbreviated dialing two-digit code and NNNNNNN is the 7 digit telephone number. An existing code may be modified with the command "$$APTABLEMODXX, NNNNNNN" where XX is the abbreviated dialing code and NNNNNNN is the new telephone number to correspond to it. An entry may be removed with the command "$$APTABLEREM XX" where XX is the abbreviated dialing code to be removed. This action frees a code for use by others.

Users may add and modify codes as needed but please be careful as codes shown as currently in the table were probably put there for use and there is no protection against modifying another users coses. The only restriction is that the telephone number must be a local area number.

As in all computer systenms, it is possible (likely) for the memory of telephone numbers to be wiped out. Periodically the table will be recorded on tape so if a wipeout occurs the table can be rebuilt to at least a reasonably recent past point.

The emergency numbers are in a separate list not accessable on the air. They are accessed by "STAR1XX". The following table gives the current contents:

CODE	SERVICE
110	Continuous weather bulletins
111	Hourly weather information
112	RAFB Weather Report
113	Aviation Weather
114	AAA Road Report
119	Mystery Number - Take a Chance!!
120	Columbus Police
122	Columbus Fire Dept.
123	Upper Arlington Police
124	Worthington Police
125	Whitehall Police
126	Reynoldsburg Police
127	Westerville Police
128	Gahanna Police
129	Franklin County Sheriff

The autopatch this repeater may be used by any licensed amateur as long as FCC Rules are observed. If full duplex operation is desired the alternate input on 52.92 MHz may used. The Patch is accessed as follows:

1. Key up on either input frequency
2. Using a touch-tone pad enter "STAR" followed immediately by the desired 7-digit telephone number or 2-digit abbreviated dialing code.
3. Release the key up or in the case of full duplex operation where this is undesirable, use the "pound sign" key of the pad to terminate the telephone number.

The repeater will check the number for validation (7 digits), automatically access the telephone line and forward the telephone number previously entered by the user. If an abbreviated dialing code was used, the corresponding telephone number will be forwarded. This action will be audible to the user. The logging recorder is also turned on at this time. If the number is invalid, no action will occur.

There is a 2.5 second timer for the interdigital interval which means that no more than 2.5 seconds may elapse between the release of a digit and the beginning of the next digit. If this time is exceeded, the digit sequence is considered invalid.

When finished with the call, release the patch by entering the touch-tone digit "POUND SIGN" then release the key up or terminate the touch-tone sequence with another "POUND SIGN". At this time the CW time and date will be sent over the repeater and the user should identify the party called as required by FCC regulations. The logging recorder will remain running for the duration of the CW time and date.

The autopatch will normally time out in 3 minutes. During the last 30 seconds of this period, a beep tone will be mixed onto the repeater audio to alert the user to the impending timeout. If during the progress of the call it is desired to reset the 3 minute autopatch timer, the touch-tone sequence 814 may be entered at any time to perform the reset. The sequence may be terminated by letting up on the mike key or by entering the touch-tone digit "POUND SIGN".

Give the directive $$Apads for a description of the abbreviated dialing feature.

The repeater linking facility allows a user to access another frequency on the 2 meter FM band through this repeater and optionally rotate a directional antenna in the proper direction. All of this may be controlled with touch-tone digits. The user of a local low-power transceiver may use this feature to access a more distant repeater which would not normally be accessable or he may access a simplex frequency with far greater range than normally available with the low-power unit.

Three steps are required to establish the link:

1. Select the transmit and receive frequencies
2. Point the antenna in the appropriate direction
3. Enable the link logic

The transmit and receive frequencies are set with a 4-digit touch-tone sequence consisting of a 2-digit transmit and a 2-digit receive code. Each 2-digit code determines the megacycle setting (145, 6 or 7) by dividing the 2-digit number by 3. If the remainder is 0 then 147 MC is used; if the remainder is 1 then 146 MC is used. The code for 146.52 simplex is 5252; the code for the 147.82/24 frequency is 8424; the code for the 147.51 simplex frequency is 151; etc. to set the frequency, enter the digits "873TTRR" where TTRR is the frequency sequence. This will establish the linking frequency but not turn on the link logic. If the sequence is accepted, a double beep will be sent upon release of the mike key.

If it is desired to set a non-standard frequency pair that does not correspond with the 30 KC spacing, there is a separate command to set the link receive and transmit frequencies. The command "877MHTF" sets the receive frequency and "878MTHF" sets the transmit frequency where M is the megacycles digit (4 through 7), H is the 100 kc digit, T is the 10KC digit and F is 5 or 0 for 5kc offset. For example, the code "8774325"sets the link receiver frequency to 144.325 MHz.

The antenna is located in northwest Columbus near Don Scott Airfield. At this location the directional antenna may be rotated to any angle in increments of 6 degrees with the digits "876XXX" where XXX is the desired angle in degrees. For instance "876135" would point the antenna to the southeast. Three digits must be supplied even if the angle is less than 100 degrees. For instance "87090" will set the antenna to 90 degrees. If the command digits are accepted, a double beep will be returned when the mike key is released. While the antenna is rotating, the repeater transmitter will not drop out and when the antenna has come to the commanded position a touch-tone sequence will be sent on 147.33 MHz indicating that the antenna has come to a stop and then the repeater transmitter will drop if no receivers are active.

An additional command is used to manage the rotator system. This is "874" which causes the rotator to calibrate against the mechanical stop. Again the repeater transmitter will not drop while the antenna is rotating.

The link logic can be arranged to listen only or talk and listen to the frequency selected. The digits "871" set the logic to listen only and the digits "870" set the logic to talk and listen. As usual the digits must be terminated with release of the mike key. When the link logic is on and there is no key down on 147.93 MHz, the receive frequency selected will be retransmitted on the repeater output. When there is a key down, the repeater input audio is retransmitted both on the repeater output and the selected transmit frequency. No beeps are generated by the repeater in this mode but the timeout timer runs during key up and key down on the 147.93 input frequency and is reset on the transition from key down to key up.

The link may be disabled with the usual reset code of "pound sign" or "813". When the link is on the only touch-tone commands that are active are:

1. Reset (pound-sign or "813")
2. Rotate antenna ("876AAA")
3. Link on ("870" or "871")
4. Set frequency ("873TTRR")(or "877MHTF" or "878MHTF")

These will not interfere with remote autopatch operation. When the link is turned off, there is no change in frequency selection or antenna position and the link may be turned on and off at will.

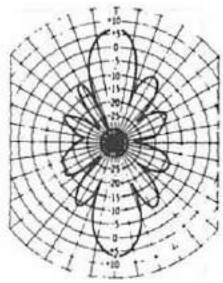
Since the complete setup of the remote base operation is complicated and somewhat dangerous if driving, a "canned" list of nearby repeaters has been put on the computer which with a single digit determines the frequency and antenna position and turns on the link. This "canned" selection is made with the touch-tone digits "875N" where N is a single digit from the following table:

8750	147.60/00 Bellfontaine
8751	147.63/03 Lancaster
8752	146.63/82 Miamisburg
8753	146.13/73 Springfield
8754	146.04/64 Delaware
8755	146.01/61 Zanesville
8756	147.99/39 Marysville
8757	147.87/27 Washington Ch
8758	147.96/36 Mansfield
8759	147.78/18 Circleville

Thus far we have seen how a microprocessor can be an "active" component in a repeater system. For an excellent example of both the hardware and software (programs) necessary to accomplish this, may I refer you to the February through May 1979, issues of *73 Magazine* for a series of articles titled "An 8080 Repeater Control System," by Robert Glasser, N3IC. It is must reading if you are considering the implementation of microprocessor control to your system.

There you have our look in to the future; a future that's just around the corner,as things are beginning to move. As Larry said earlier, the microprocessor and mini-computer are here to stay and, if I may say so, they are a welcome addition indeed. Who knows, in a few years our stations may be talking to one another—without us.

Chapter 46
Bells, Whistles, Goodies, and Conversions



The hookup shown here is for an ME3 decoder, but it is the same for any decoder with a similar output impedance, audio output, and DC power requirements.

Figure 46-1 shows the quick and dirty way to hook it up, and Fig. 46-2 shows the right way to do it. The Midland 13-513 has an extra switch deck that can be used to switch tone elements into the ME3. The Clegg does not have this spare deck. If you have a 13-509 and use this deck to switch elements, short any unused positions. Do not turn off the PL by unplugging, the element, as the ME3 may oscillate at 10 to 15 Hz. Shorting doesn't hurt it.

ENCODE AND DECODE

Figure 46-2 shows the connections for the Com-Spec TS1 board. It can be mounted inside the rear of the transceiver, in the relay compartment, near the antenna connector. It is not necessary to hook up the high-pass filter, but desirable.

The AP8/TS1 combination makes multiple encode/decode easy in this unit. An ME3 and connections are shown in Fig. 46-3, for decode only, in the 13-513. Connections for encode and decode are shown in Fig. 46-4. The TS1-JR is the same as the TS1, except that it is smaller and has no receive-audio filter.

CONSTRUCTION

Portions of the instruction booklet and the schematic diagram for the Com-Spec TS1 are reproduced, with permission, on the following pages. Figure 46-5 is the schematic diagram and parts-placement guide, and Table 46-1 is a parts list.

TS-1 HOOK-UP INSTRUCTIONS

Mounting

Mount unit with hardware supplied. When using a 90 degree angle bracket against the PCB, be sure to *use the two fiber spacers provided* between the angle bracket and the PCB. If this is not done, the bracket will short out the foils on the PCB.

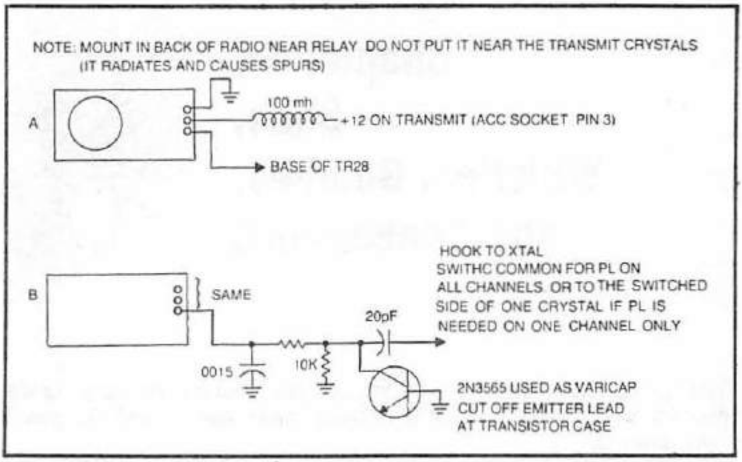

NOTE: MOUNT IN BACK OF RADIO NEAR RELAY DO NOT PUT IT NEAR THE TRANSMIT CRYSTALS
(IT RADIATES AND CAUSES SPURS)
A
100 mh
+12 ON TRANSMIT (ACC SOCKET PIN 3)
BASE OF TR28
B
SAME
HOOK TO XTAL
SWITHC COMMON FOR PL ON
ALL CHANNELS OR TO THE SWITCHED
SIDE OF ONE CRYSTAL IF PL IS
NEEDED ON ONE CHANNEL ONLY
20pF
10K
0015
2N3565 USED AS VARICAP
CUT OFF EMITTER LEAD
AT TRANSISTOR CASE

Fig. 46-1. Connecting the ME3 encoder to the transceiver.

Jumper Placement

If jumpers are used in JU1 or JU2, be sure to solder the eyelets to the foil as well as the jumper wires. Jumper JU1 is used to select the proper frequency range for the unit. Jumper JU1 is *out* for the lo range of 67.0Hz to 131.8Hz. Jumper JU1 is *in* for the hi range of 136.5Hz to 203.5Hz. If you do not have JU1 in or out as required for the desired frequency, THE FREQUENCY WILL BE EITHER ½ OR TWICE THE CORRECT FREQUENCY EXACTLY. Refer to squelch gating section for proper installation of JU2.

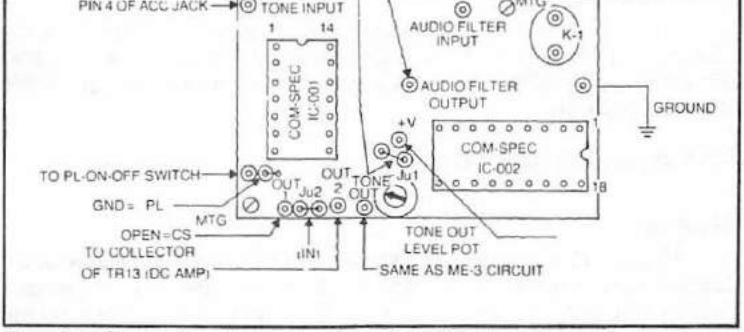


Fig. 46-2. Connections to use the Com-Spec TS-1 board.

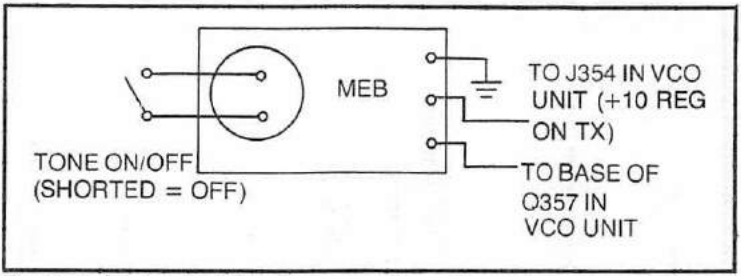

MEB
TO J354 IN VCO UNIT (+10 REG ON TX)
TONE ON/OFF (SHORTED = OFF)
TO BASE OF Q357 IN VCO UNIT

Fig. 46-3. Turning the ME3 tone on or off.

Power Hook-Up

Hook +V on PCB to +6 to +16vdc continuous. It is preferable to use +12vdc as a supply voltage if high tone output is needed as output voltage is a function of supply voltage. Hook GND on PCB to chassis ground in negative ground systems. If positive ground operation is required, interchange GND and +V connections and also make proper provisions for returning mike hand-up to +V instead of ground. If polarity is reversed to the unit, it will not operate but will not be damaged. Use the following as a guide for obtaining proper operating voltage.

Mobiles, 12v negative ground—standard hook-up

Mobiles, 12v positive ground—reverse board +V and GND connections, return mike hang-up to +V instead of ground

Mobiles, 6v positive or negative ground—use B+ dropping method figure 1.2

Bases—Use appropriate figure 1.0, 1.1, or 1.2

Tone Output

Tone may be added to most transmitters directly to the center of the mod pot or to the modulator grid through a large value resistor of 100k or

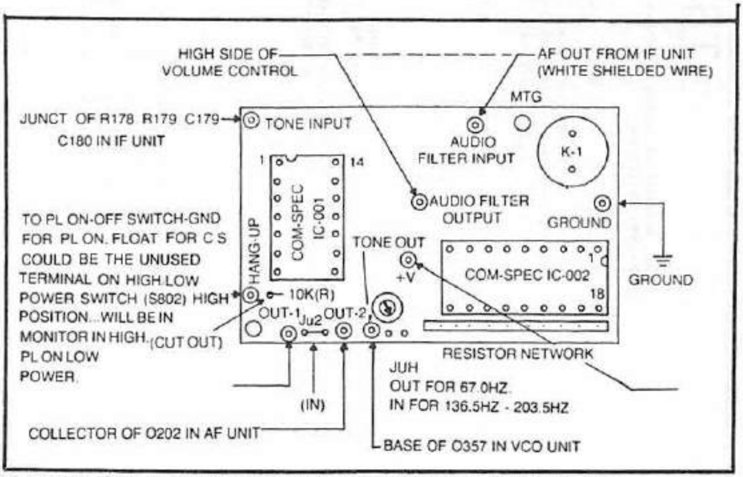
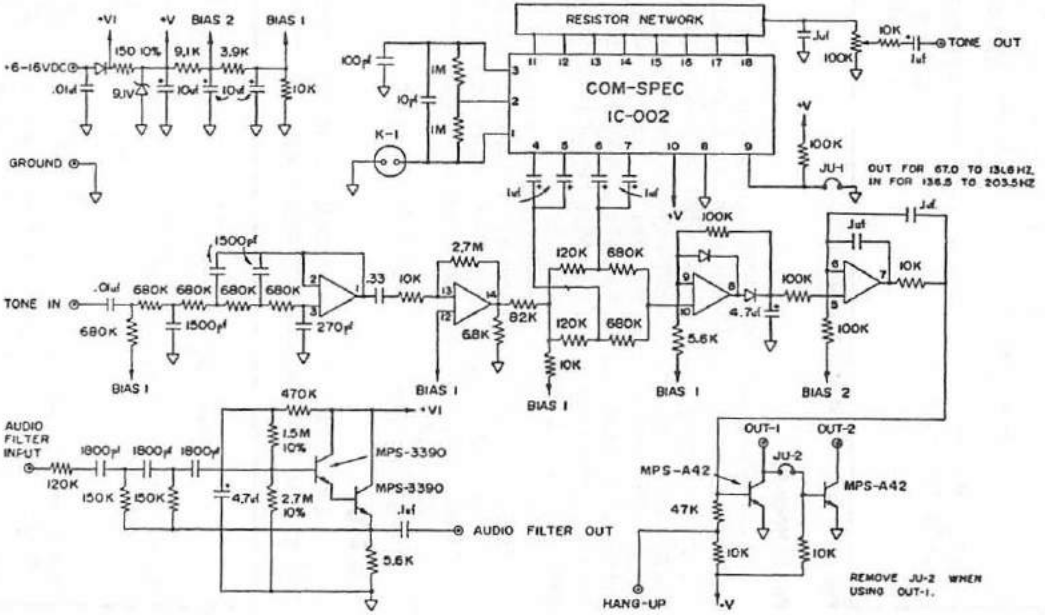

HIGH SIDE OF VOLUME CONTROL
AF OUT FROM IF UNIT (WHITE SHIELDED WIRE)
MTG
JUNCT OF R178 R179 C179 C180 IN IF UNIT
TONE INPUT
AUDIO FILTER INPUT
K-1
1
14
COM-SPEC IC-001
AUDIO FILTER OUTPUT
GROUND
TO PL ON-OFF SWITCH-GND FOR PL ON. FLOAT FOR C S COULD BE THE UNUSED TERMINAL ON HIGH LOW POWER SWITCH (S802) HIGH POSITION...WILL BE IN MONITOR IN HIGH PL ON LOW POWER.
HANG-UP
TONE OUT
+V
COM-SPEC IC-002
1
18
GROUND
10K(R)
(CUT OUT)
OUT-1
Ju2
OUT-2
RESISTOR NETWORK
JUH
OUT FOR 67.0HZ
IN FOR 136.5HZ - 203.5HZ
(IN)
COLLECTOR OF Q202 IN AF UNIT
BASE OF Q357 IN VCO UNIT

Fig. 46-4. Connections for encoding and decoding in the 13-513.

TS-1 INSTRUCTION SHEET

ALL RESISTORS 5% UNLESS OTHERWISE SPECIFIED
K=1,000 M=1,000,000



OUT FOR 67.0 TO 131.8 HZ.
IN FOR 136.5 TO 203.5 HZ

REMOVE JU-2 WHEN USING OUT-1.

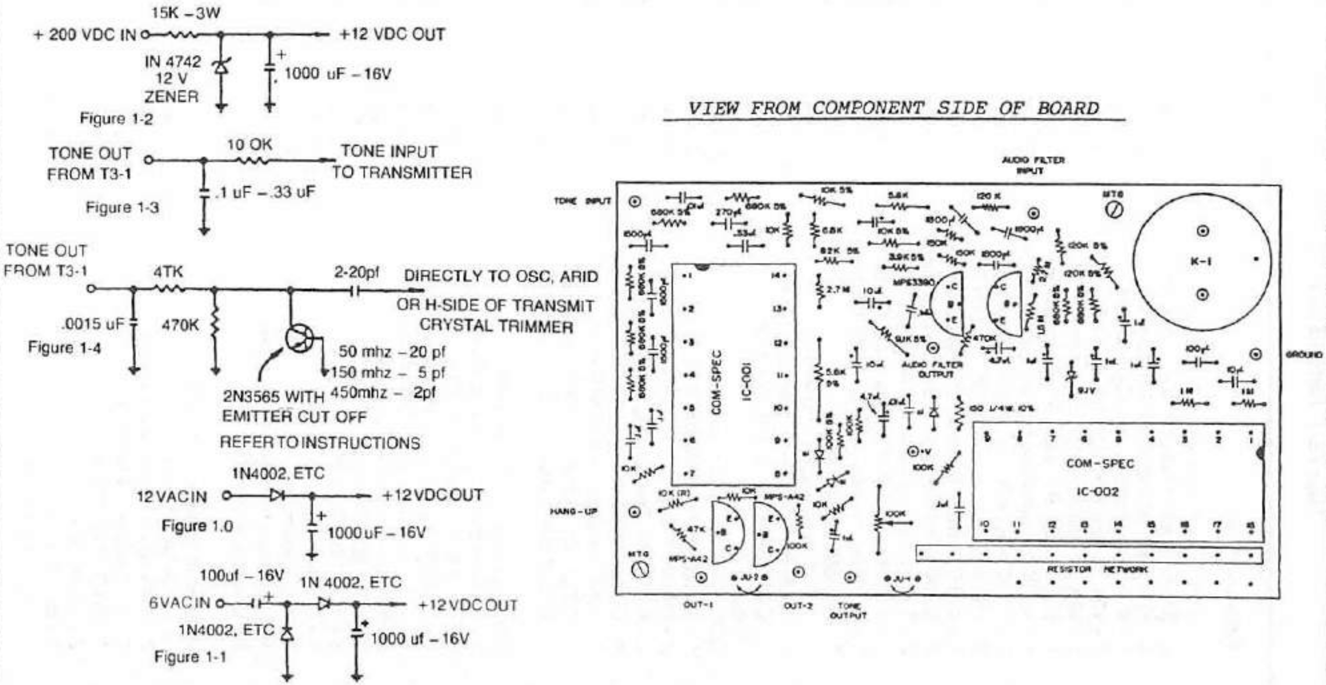


Fig. 46-5. Schematic diagram and parts placement for the Com-Spec TS-1 board.

Table 46-1. Parts list for the TS-1.

Parts List - TS-1

1 - 3.9K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
2 - 5.6 K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
1 - K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
1 - K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
7 - 10K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
1 - 47K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
1 - 82K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
4 - 10CK ⅛ watt Resistor, 5% Carbon Film	.31 ea.
3 - 120K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
2 - 150 K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
1 - 470K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
7 - 680K ⅛ watt Resistor, 5% Carbon Film	.31 ea.
2 - 1 Meg. ⅛ watt Resistor, 5% Carbon Film	.31 ea.
1 - 1.5 Meg. ⅛ watt Resistor, 10% Carbon Comp.	.22 ea.
2 - 2.7 Meg. ⅛ watt Resistor, 10% Carbon Comp.	.22 ea.
1 - Resistor Network	2.50 ea.
1 - 150 ohm ¼ watt Resistor, 10%	.10 ea.
1 - 100K Potentiometer, Mepco ET14W	1.39 ea.
1 - COM-SPEC IC-001 microcircuit	3
00 ea.	1
COM-SPEC IC-002 microcircuit	17.50 ea.
1 - 1N5239B Zener diode, 9.1v	1.05 ea.
2 - MPSA42 Transistors, NPN, Silicon	.85 ea.
2 - MPS3390 Transistors, NPN, Silicon	.49 ea.
3 - Diodes, Silicon	.15 ea.
1 - 10pf 50v Capacitor, CN15 ceramic	1.00 ea.
1 - 100pf 50v Capacitor, CW15 ceramic	1.00 ea.
1 - 270 pf 50v Capacitor, CN15 ceramic	1.00 ea
	3 - 1500pf
50v Capacitor, CW15 ceramic	1.25 ea.
3 - 1800 pf 50v Capacitor, CW15 ceramic	1.25 ea.
2 - .01uf 50v Capacitor, CW15 ceramic	1.50 ea.
4 - .1uf 50v Capacitor, CW15 ceramic	2.00 ea.
1 - .33uf 50v Capacitor, CW15 ceramic	2.25 ea.
5 - 1uf 35v Capacitor, Tantalum	.84 ea.
2 - 4.7uf 20v Capacitor, Tantalum	.87 ea.
3 - 10uf 16v Capacitor, Tantalum	.92 ea.
1 - Printed Circuit Board	6.00 ea.
2 - K-1 Socket pins	.25 ea.
1 -1 K-1 element (specify frequency)	3.00 ea.
9 - Chassis terminals	.10 ea
	8 - Sets
wires with push-on terminals	
attached (colored)	2.00 set
2 - 4-40 spacers with 4-40 screws	.15 ea.
2 - 4-40 angles, 90 degree	.15 ea.
2 - 4-40 Fiber spacers	.05 ea.
2 - wiper wires	.01 ea.
1 - pin IC socket	.49 ea.
1 - 18 pin IC socket	.69 ea.

so. Use shielded wire with tube type circuits. Some older tube type transmitters accept tone more readily if injected with a crystal modulator circuit. Various values of coupling capacitors are shown for the different frequency ranges of the transmitter. The Varicap (transistor base to collector junction of an NPN silicon transistor) changes AC voltage into changing capacitance which truely FM modulates the transmitter. No intermoding or distortion of the voice will be noted with this method. Varicap networks are available from us for $3.00 each. If tone is injected into a phase modulator, it is possible for a slight amount of high frequency component to be amplified along with the low frequency tone.

Hang-up

In normal operation, the hang-up lead is grounded by the mike hookswitch until the mike is removed from the hanger. Ungrounding the hang-up pin allows the switching circuit to unmute the receiver for monitoring of the channel prior to transmitting. Resistor R (10k) is cut out if +V is supplied to the hang-up terminal with the mike off the hanger and no voltage if it is hung-up as in the RCA types of radios. Some mikes have the hang-up wire in the mike cord going to the rear mounting of the mike so no extra hang-up hookswitch is required.

Decoder Input

Hook tone input on board directly to the discriminator of the receiver forward of any metering resistance going to the discriminator jack. Some receivers provide amplified audio which is used to drive factory installed tone decoders. If your receiver has such an amplifier in it, it may be used. In tube type receivers, shielded wire may be necessary.

Audio Filter

Cut audio path in receiver and hook-up input and output wires in series with that broken path. The discriminator, where the input to the tone decoder is hooked is usually a good spot. The center of the volume control in some receivers is a good place also. Receivers that incorporate factory installed tone decoders have high pass filters in them or on the tone deck. Hook-up should be where that filter would have been connected. Use shielded wire if hum is present in the audio after filter installation.

Squelch Gating

The TS-1 uses 330v switching transistors to provide solid state receiver muting. Both a pull to ground upon receipt of proper tone (or lifting of the hookswitch) and a pull away from ground are provided for in the circuit. By the correct selection of Out 1 or Out 2 and JU2 in or out, any type of receiver, tube or transistor may be switched. If a tube type squelch circuit is to be gated, usually a large value of resistance (1meg) is inserted in series with the selected Out 1 or Out 2. If it is required that a relay be driven, a coil of 185 ohms or so may be used. One side of the relay coil is connected to +V and the other side is connected to Out 1 with JU2 out. The relay will energize upon receipt of proper tone or removal of the mike from the hookswitch.

Table 46-2. Troubleshooting chart for the TS-1.

(1) Remove connections on TS-1 from tone input, tone output and OUT-2
(2) To test OUT-1 and OUT-2, connect a 10K resistor from +V to OUT-1 or OUT-2 respectively. When testing OUT-1, be sure to remove JU-2

PROBLEM	POSSIBLE CAUSE	TEST PROCEDURE
No encode or decode	Zener shorted	Check for +V at zener
	Open power supply diode	Check for continuity
	Bad IC-002	Replace with known good IC
	10uf capacitor shorted in power supply	Replace
	Circuit board damaged or shorted	Inspect
	JU-1 installed improperly	Read instructions on JU-1 placement
	Improper hook-up	Consult factory for hook-up to your particular model
No encode	Broken 10K series resistor	Replace
	Defective IC-002	Replace
	Defective 100pf in oscillator	Remove from circuit, retest
	Defective 10pf in oscillator	Replace
	Defective potentiometer	Replace
No decode	Defective IC-00	Replace
	Output transistor(s) damaged	Check for decode switching action on pin 7 of IC-001
Note: Decoder may be checked by looping tone output back to decode input with jumper wire	JU-2 installed improperly	Read instructions for JU-2 hook-up
	Broken 10K at pin 7 of IC-001	Replace
	Open 270pf on pin 3 of IC-001	Square waves will appear on pin 14 of IC-001 with no signal present
	Broken resistors around edge of board 10K, 100K, 120K, etc.	Replace
No hang up	Broken 10K or 47K on hang-up circuit	Replace
	Output transistors(s) damaged	See "no decode" above
	Improper hook-up	Consult factory for proper connections
	Shorted 1uf from pin 7 to 6 on IC-001	Remove and retest
Decoder locked up	Output transistor(s) damaged	See "no decode" above
	Improper hook up	See "no decode" above
Decoder pops in and out	Bad IC-002	Replace
	Bad 100K from pin 9 of IC-001 to 4.7uf capacitor	Replace
	Broken 120K or 680K in digital filter	Replace
Coder off frequency	Check JU-1 for proper placement	See instructions of JU-1
	Bad K-1 element	Replace
	Bad IC-002	Replace
	Bad 10pf or 100pf in oscillator circuit	Replace
No audio through audio filter	Open 1800pf capacitor	Check AC continuity through filter
	Bad MPS3390 transistor	Replace
	Broken 150K resistor	Replace
	Improper hook-up	Consult factory for proper connections
Distorted audio through filter	Check for broken 1.5M or 2.7M resistor on base of MPS3390	Replace
	Improper impedance match	Use 120K series resistor on input to audio filter
Intermittent decoder	Bad IC-002	Replace
	Open 270pf on pin 3 of IC-001	See "no decode" above
	Broken resistor around outside of board 10K, 120K, 680K, etc.	Replace
Encoder tone modulates voice excessively	Excessive level	Reduce tone level
	Improper hook-up	Consult factory for proper connections
Encoder has too much level or loads down voice mod or is distorted	Excessive tone level	Use series resistor in tone output
	Voice modulated or distorted	Connect .1uf capacitor from tone output to ground

Out 1	JU2 out	Transistor pulls Out 1 to ground upon receipt of proper tone.
Out 2	JU2 in	Transistor pulls Out 2 away from ground upon receipt of proper tone.

A functional block diagram of the TS1 is shown in Fig. 46-6, and Table 46-2 is a trouble-shooting guide for the decoder.

The TS1-JR is a smaller version of the TS1, and the schematic diagram is given in Fig. 46-7, and the parts list in Table 46-3.

TS-1JR HOOK-UP INSTRUCTIONS

Mounting

Mount the unit with double-sided sticky tape, a dab of hot glue, or RTV Silicone, etc. Use no more than is necessary to keep the unit from moving.

Jumper Placement

Jumper JU-1 is used to select the proper frequency range for the unit. Jumper JU-1 is *out* for the low range (67.0 to 131.8 Hz) and *in* for the high range (136.5 to 203.5 Hz). If JU-1 is not properly installed, *the frequency will be either 1/2 or twice the correct frequency, exactly.*

67.0 - 131.8 Hz. Low range JU-1 Out
136.5 - 203.5 Hz. High range JU-1 In

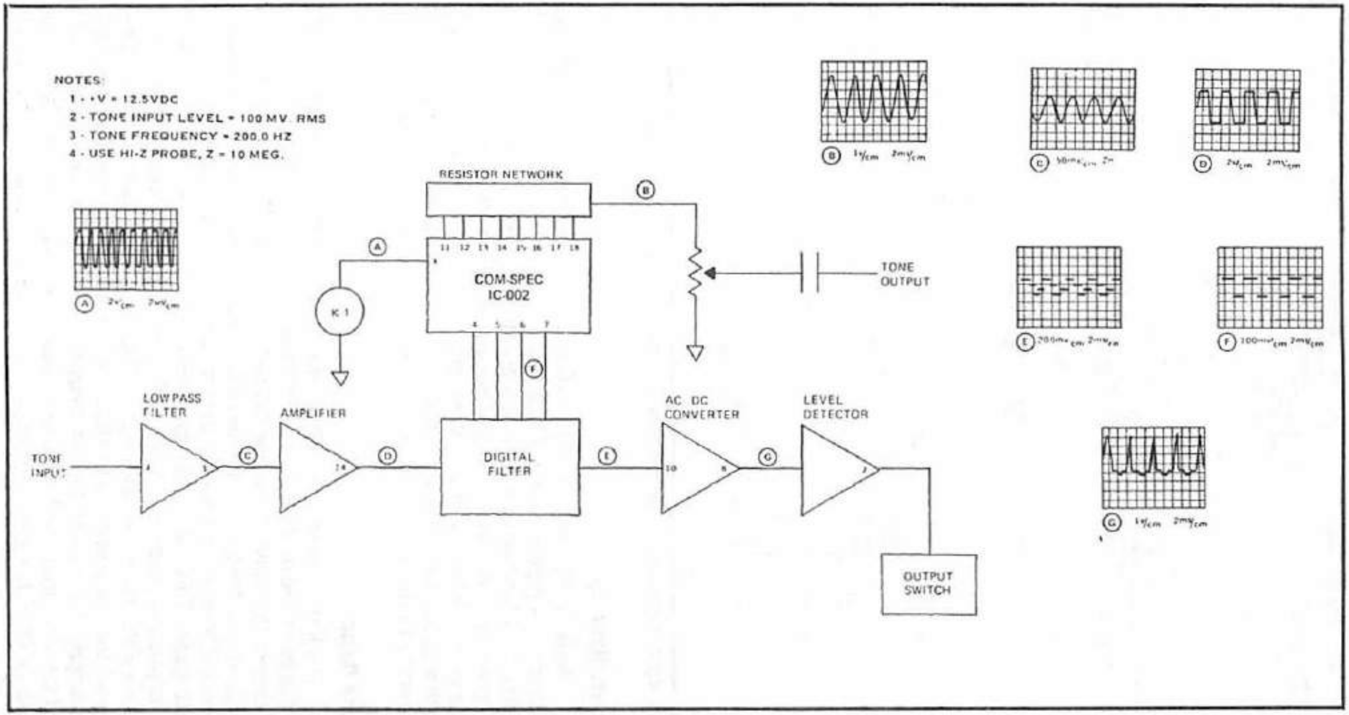


Fig. 46-6. Functional block diagram of the TS-1.

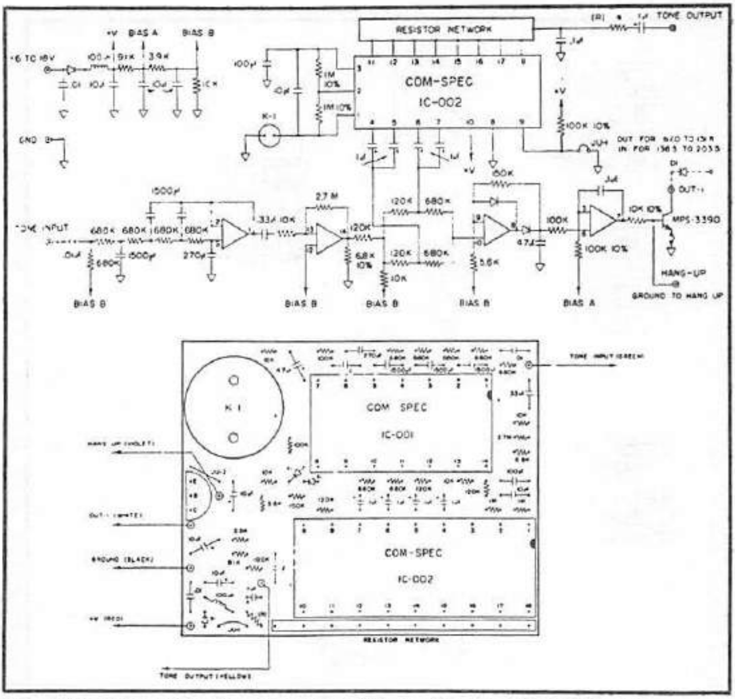


Fig. 46-7. Schematic diagram and part layout for the TS-1JR board.

Power Hook-Up

Hook the Red wire to +6 to +16vdc continuous. It is preferable to use +12vdc as a supply voltage if high tone output is needed because output voltage is a function of supply voltage. Hook the Black wire to ground in negative ground systems. If positive ground operation is required, interchange the Red and Black wires and also make proper provision for returning the Violet hang-up wire to +V instead of ground. If polarity is reversed to the unit, it will not operate but will not be damaged.

Tone Output

Hook the Yellow tone output wire directly to the center of the MOD pot in most late model solid-state transmitters. If insufficient tone level is obtained, the value of resistor (R) can be lowered. This value is 100K as shipped from the factory. If tone level is still insufficient, go back one stage from the Mod pot and connect the tone input to the base of the transistor in that stage. This will usually give more than adequate level which might prompt adding more resistance (50K-1 meg) in series with the Yellow lead to keep the tone level at about ±.75kc. If tone is injected into a phase modulator, it is possible for a slight amount of high frequency component to be amplified along with the low frequency tone. If this is noticeable, add a .luf capacitor from the Yellow tone output lead to ground and a large value resistor (22K-1meg) from the capacitor and Yellow lead junction in series to the injection point in the transmitter. This resistor and capacitor network will form an effective low-pass filter.

Tone Input

Hook the Green tone input wire directly to the discriminator of the receiver forward of any metering resistance going to the discriminator jack. The high side of the volume control is usually connected to the discriminator output and therefore makes a convenient connection point.

Squelch Gating and Hang-Up

The TS-1JR uses a 25v switching transistor to provide solid-state receiver muting. A pull away from ground is provided at OUT-1 (White wire) either upon receipt of proper tone or *grounding* of the Violet hang-up wire. If the Violet hang-up wire is wired to the base of the transistor as shown and the jumper is *in* from its emitter to ground, grounding the Violet wire will force the transistor OFF and allow the receiver to monitor. Diode

Table 46-3. Parts list for the TS-1JR.

Parts List - TS-1JR	
1 - 3.9K Resistor, ⅛ watt, 5%	.31 ea.
1 - 5.6K Resistor, ⅛ watt, 5%	.31 ea.
1 - 6.8K Resistor, ⅛ watt, 5%	.22 ea.
1 - 9.1K Resistor, ⅛ watt, 5%	.31 ea.
2 - 10K Resistor, ⅛ watt, 5%	.31 ea.
2 - 10K Resistor, ⅛ watt, 5%	.22 ea.
4 - 100K Resistor, ⅛ watt, 5%	.22 ea.
3 - 120K Resistor, ⅛ watt, 5%	.31 ea.
1 - 150K Resistor, ⅛ watt, 5%	.31 ea.
7 - 680K Resistor, ⅛ watt, 5%	.31 ea.
2 - 1 Meg. Resistor, ⅛ watt, 10%	.22 ea.
1 - 2.7 Meg. Resistor, ⅛ watt, 10%	.22 ea.
1 - 8 Resistor Network	2.50 ea.
1 - 100uh. Choke	1.29 ea.
1 - Com-Spec IC-001 Microcircuit	3.00 ea.
1 - Com-Spec IC-002 Microcircuit	17.50 ea.
1 - Transistor, MPS3390	.49 ea.
3 - Diodes, Silicon	.15 ea.
1 - 10pf. Capacitor, CN15 Ceramic Mono.	1.00 ea.
1 - 100 pf. Capacitor, CN15 Ceramic Mono.	1.00 ea.
1 - 270pf. Capacitor, CN15 Ceramic Mono.	1.00 ea.
3 - 1500pf. Capacitor, CW15 Ceramic Mono.	1.25 ea.
2 - .01uf. Capacitor, CW15 Ceramic Mono.	1.50 ea.
2 - .1uf. Capacitor, CW15 Ceramic Mono.	2.00 ea.
1 - .33uf. Capacitor, CW15 Ceramic Mono.	2.25 ea.
5 - 1uf. Capacitor, 20v. Tantalum	.84 ea.
1 - 4.7uf. Capacitor 20v. Tantalum	.87 ea.
3 - 10uf. Capacitor, 16v. Tantalum	.92 ea.
1 - Printed Circuit Board	12.00 ea.
2 - K-1 Socket Pins	.25 ea.
1 - K-1 element	3.00 ea
6 - Wires, Colored, #30, 12" long	.10 ea.

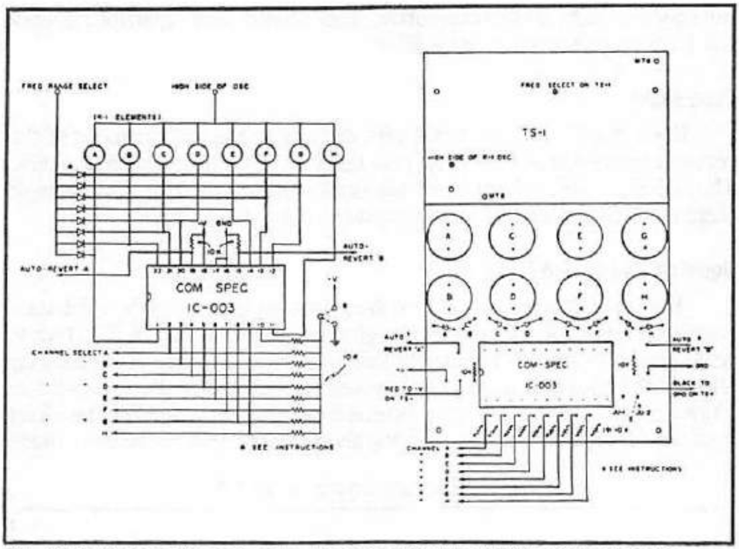


Fig. 46-8. Schematic and parts placement for the AP-8 adapter board.

D1 is not required when the Violet wire is connected to the base of the transistor. If the jumper from the emitter to ground is removed and the Violet lead is connected to the emitter of the transistor, removing the Violet wire from ground will allow the receiver to monitor. If this hook-up is used, diode D1 must be installed. The jumper from the emitter to ground is shown as JU-2 on the pictorial diagram. Diode D1 is a silicon diode similar to a 1N4148.

ADAPTER PANEL

The AP-8 is an adapter panel that converts the TS-1 to an 8-tone unit. The schematic diagram for the AP-8 is given in Fig. 46-8, and the parts list is in Table 46-4.

AP-8 HOOK-UP INSTRUCTIONS

The AP-8 adapter panel accepts a TS-1 unit and makes it 8 tone channels both send and receive. It also has provisions to automatically revert to a common decode frequency on receive irrespective of the position the selector switch was left in.

1. Plug-in the desired K-1 elements in positions A through H in proper order.
2. Diodes A through H must be installed at each position that a K-1 element of 136.5-203.5Hz is installed. This is the High range. All elements that are Low range (67.0-131.8Hz) must have their respective diodes clipped or removed from the circuit. If this is not done *the frequency will be 1/2 or twice normal, exactly*.
3. The TS-1 should be modified by clipping out the small 470pf blue monolithic capacitor closest to the K-1 element socket. This capacitor is marked 471 and one side is grounded to the GND pin.

If a 100pf (marked 101) capacitor is present in the TS-1 it may be left in if desired with only a very small effect on the frequency (approximately .1Hz lower in frequency).

4. The frequency jumper JU-1 on the TS-1 should be removed if it is present and a wire soldered to the eyelet that is *not* ground. This wire should protrude ½" or so on the bottom side of the board.
5. The TS-1 can now be mounted with screws, fiber washers and nuts. The frequency select lead will fit in the Frequency select hole on the AP-8 and can be soldered down. A jumper wire must be added from the ungrounded K-1 socket pin to High side of K-1 on the AP-8 and soldered. Note that no K-1 element will be installed in the TS-1 itself.
6. The red wire can be plugged into +V on the TS-1 and the Black wire into GND. All other pins on the TS-1 may be used as if no AP-8 was attached.
7. +V is connected to +6 to +16vdc and GND is connected to Ground.
8. If ground is being supplied to switch the elements, the violet jumper wire must be installed in JU-1. If +V is being used to switch the elements, the violet jumper wire must be installed at JU-2. NOTE: If +V is being used, it must be greater than ½ the +V voltage supplied to the AP-8.
9. If NO automatic reverting on receive is desired (i.e. selector switch is active in both send and receive) hook GND to Auto Revert "A" *OR* +V to Auto Revert "B" *BUT NOT BOTH*.
10. If automatic reverting on receive is desired (i.e. selector switch is active in transmit only but element "A" is selected during receive) hook Keyed +V on transmit to Auto Revert "B" *OR* Keyed Ground to Auto Revert "A" *BUT NOT BOTH*.

HP-1A TONE FILTER

Schematic diagram and parts placement for the HP-1A is shown in Fig. 46-9, and the parts list in Table 46-5.

Table 46-4. Parts list for the AP-8.

Parts List - AP-8	
11 - 10K, ⅛ watt Resistor, 10%	.22 ea.
1 - IC Socket, 22 pin	1.10 ea.
16 - K-1 Socket pins	.25 ea.
1 - Printed Circuit Board	4.10 ea.
1 - Com-Spec IC-003 Microcircuit	10.00 ea.
14 - Chassis terminals	.10 ea.
1 - 3" Black wire w/receptacle (1)	.25 ea.
1 - 3" Red wire w/receptacle (1)	.25 ea.
8 - Diodes, Silicon	.15 ea.
4 - Fiber Spacers	.05 ea.
10 - 4-40 Screws w/nuts	.05 ea.
4 - 4-40 Spacers	.15 ea.
2 - 4-40 Angles, 90 degree	.05 ea.

Table 46-5. Parts list for the HP-1A board.

PARTS LIST

1 - 5.6K ⅛ watt resistor, 5% carbon film	$.31 ea.
1 - 120K ⅛ watt resistor, 5% carbon film	.31 ea.
2 - 150K ⅛ watt resistor, 5% carbon film	.31 ea.
1 - 470K ⅛ watt resistor, 5% carbon film	.31 ea.
1 - 1.5M ⅛ watt resistor, 10% carbon Comp	.22 ea.
1 - 2.7M ⅛ watt resistor, 10% carbon Comp	.22 ea.
2 - MPS3390 Transistors, NPN, Silicon	.49 ea.
3 - 1800pf, 50v Capacitor, CW15 ceramic	1.25 ea.
1 - .1uf, 50v Capacitor, CW15 ceramic	2.00 ea.
1 - 10uf, 20v Capacitor, Tantalum	.87 ea
1 - Printed Circuit Board	2.00 ea.
4 - Wires, colored #28, 12" long	.10 ea.
1 - 4-40 angle, 90 degrees	.15 ea.
1 - 4-40 spacer with (2) 4-40 screws	.15 ea.

Hook-Up Instructions

1. Mount the board with the hardware supplied.
2. Hook-up red wire to +6 to 12vdc and black wire to ground.
3. Cut audio path in receiver and hook-up HP-1A input wire (yellow) and output wire (violet) in series with that broken path. The discriminator, where the input to the tone decoder is hooked is usually a good spot. Receivers that incorporate factory tone have high-pass filters in them or on the tone deck. Hook-up should be where that filter would have been connected. Use shielded wire if hum is present in the audio after installation.

ME-3 TONE ENCODER

A pc board layout, parts placement, schematic diagram, and connections to modulate a crystal oscillator are shown in Fig. 46-10, and the parts list, with band-change values for different tones given in Table 46-6.

Mounting

The unit is mounted with a ½w resistor lead (not supplied) about ½" long. Solder one end to the terminal of the correct polarity desired. The other end of the lead is soldered to the PCB or chassis in the radio unit. See above diagram for correct hook-up. In portable units, the encoder may be insulated with tape or its equivalent and placed inside unit with no mounting. The unit is immune to RF.

Power Hook-Up

The voltage to the encoder MUST be keyed with the transmitter in most mobile units. This is because the encoder operates in the fundamental mode around the IF frequencies of some receivers. If keyed voltage is not available, an RF choke of 10 μh to 100μh may be placed in series with the voltage supply to the encoder to eliminate the problem. Use the above diagram to apply correct polarity to the unit. If the polarity is reversed, the unit will not operate but it will NOT be damaged. If it is necessary to operate the encoder off supplies greater than 16vdc, use the following formula to determine the correct series dropping resistor value. R= Supply voltage−12 divided by .008. If "T" whine, vibrator hash, or AC hum are present in the tone output, add a 220 ohm ¼w resistor in series with the supply lead and the encoder and bypass this point to the negative supply (or GND) with a 100uf−16v capacitor. For base operation in tube-type units, the −20v bias supply will provide adequate voltage with a lk series dropping resistor.

Tone Output

Tone may be added to most transmitters directly to the center of the mod pot or directly to the modulator grid (or base in a transistorized transmitter). Note that a 10k series resistor is provided internally in the encoder so no other series resistance should be needed. If more tone level is required, the input voltage may be raised to a level closer to 15vdc. Some of the older tube type transmitters accept sub-audible tone more readily if injected with a crystal modulator circuit as shown above. Various values of coupling capacitance are shown for the different frequency ranges of the transmitter. The Varicap (or transistor base to collector junction with the emitter cut off) changes AC voltage into changing capacitance which truely FM modulates the transmitter. No intermoding or distortion of the voice will be noted with this method.

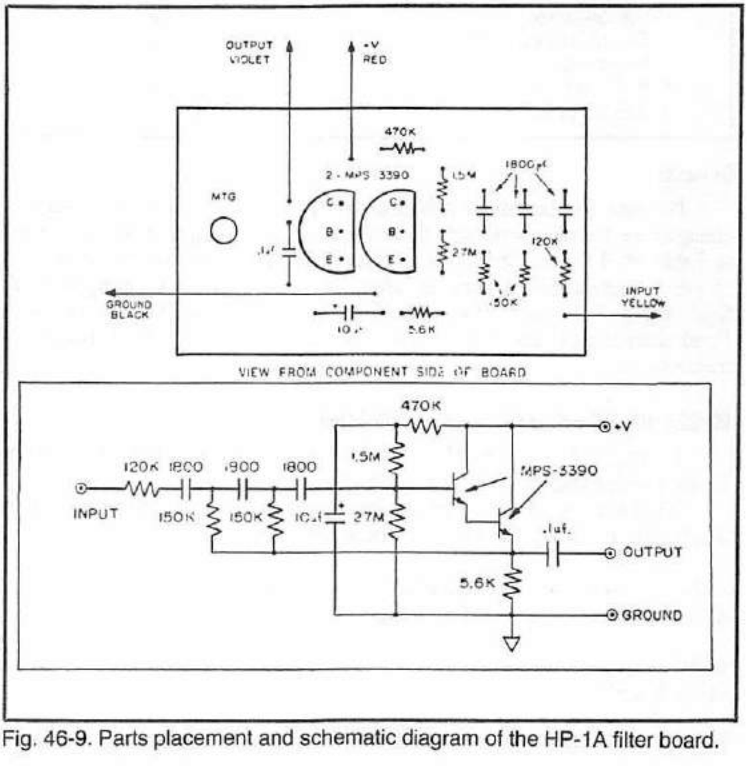


Fig. 46-9. Parts placement and schematic diagram of the HP-1A filter board.

Table 46-6. Parts list and tone-band change values for the ME-3.

BAND CHANGE VALUES

	67.0-131.8 Hz	136.5-203.5 Hz
C2	.015uf	.01uf
C3	NONE	NONE-56pf
R1	IN	OUT
R2	OUT	IN

PARTS LIST

1- 10k 1/8 w	.25 ea
2- 100k 1/8w	.25 ea
1- 100 k pot	1.75 ea
1- 10pf CN15 "NPO" ceramic	1.00 ea
1- 470pf CN15 "NPO" ceramic	1.00 ea
1- 4700pf CW15 "W" ceramic C1	1.25 ea
1- .01 uf CW15 "W" ceramic C2	1.50 ea
or .015uf CW15 "W" ceramic C2	1.75 ea
1- 0-56pf CN15 "NPO" ceramic C3	1.00 ea
1- 1uf-35v tant. cap.	.85 ea
1- Silicon diode	.15 ea
1- Drilled, plated PCB	2.00 ea
1- Microcircuit	15.00 ea
1- K-1 element	3.00 ea
2- Socket pins	.25 ea

General

Be sure the terminals are soldered to the foil. If it is nesessary to change tone frequency outside the band the unit was shipped on, see the list in Table 46-6 for the proper band change parts values. Also note that C3 should be cut out (if it is present) anytime tone frequency is changed in the field. Any K-1 elements shipped for field replacement will *NOT* require C3. Band change parts may be ordered from the parts list for field changes in frequency.

IC-22S ON 20 kHz AND 30 kHz SPACING

From the Western Washington Amateur Relay Association comes this tid-bit concerning the ICOM IC-22S. See Fig. 46-1.

The idea behind the modification is to move the transceivers frequency down either 5 kHz, L0 kHz, or not at all.

C1N is selected for a 5 kHz change
C2 is selected for a L0 kHz change

R1N is connected to the least significant program bit or DO coming from the diode board.

R2N is connected either to a diode or diodes as shown in Fig. 46-11A.

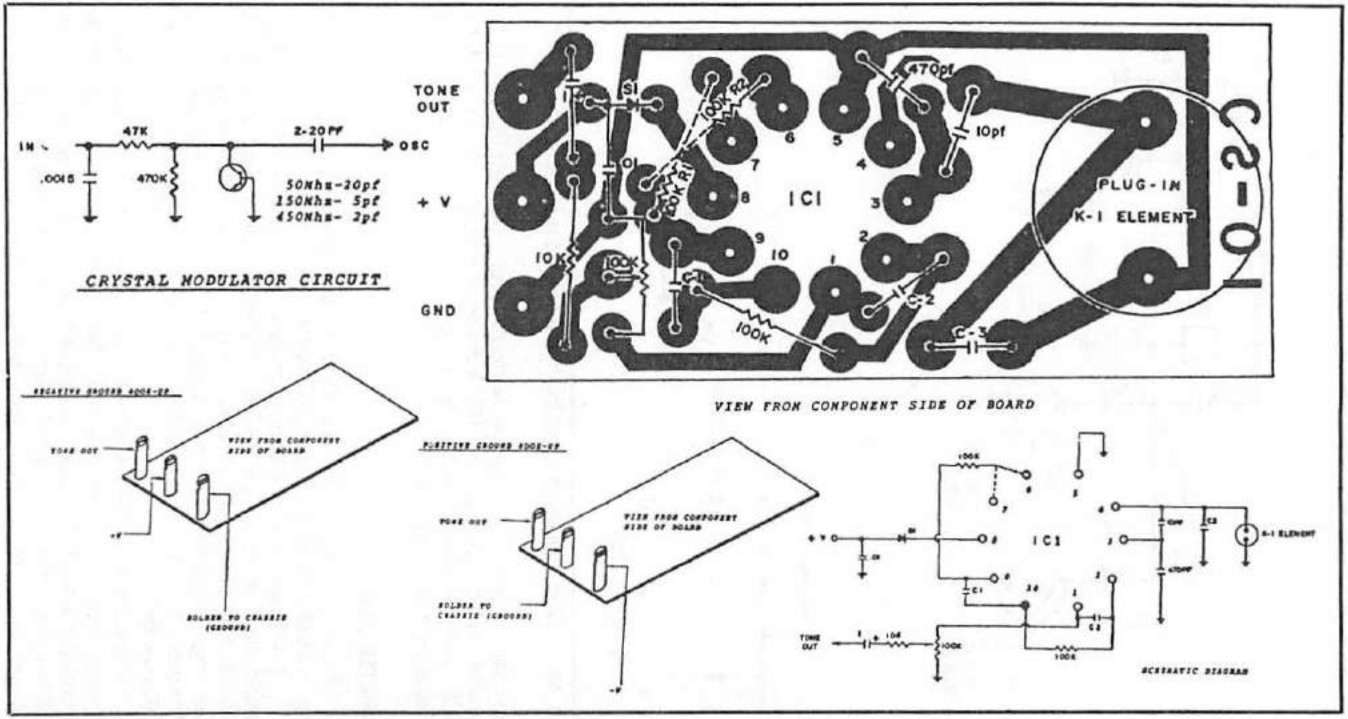


Fig. 46-10. PC board, parts placement, schematic and connections for the ME-3 encoder.

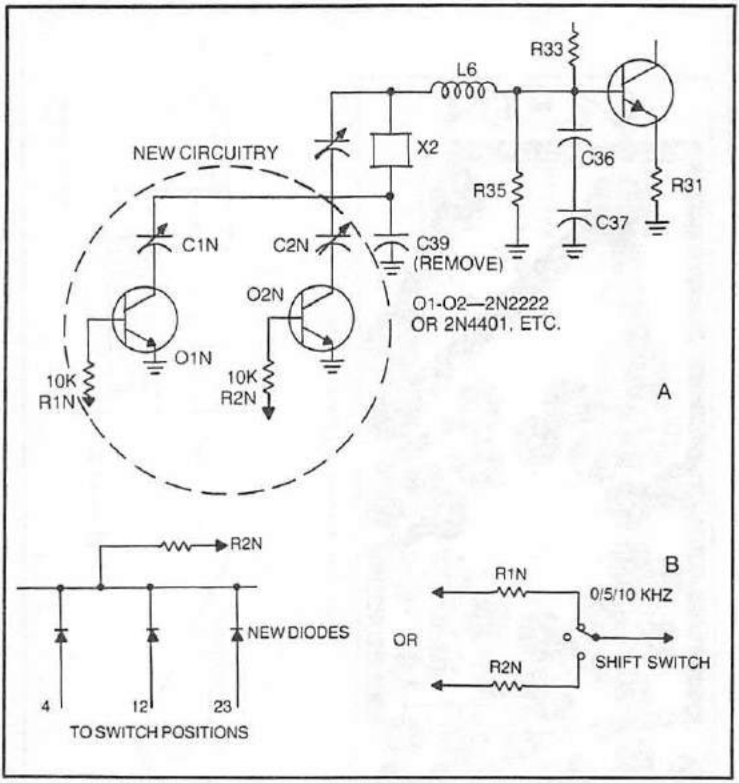


Fig. 46-11. Modifications to lower the frequency of the IC-22S.

An example would be: Position 12 might be programmed for 147.03 the new frequency desired is 147.02. A diode connected from position 12 to R2N will move the radio from 03 to 02 or down 10 kHz. R2 could be connected to an external switch.

S-METER LIGHT

From *220 Notes* of October, 1978, comes the circuit in Fig. 46-12. It was originally by Joe LeKostaj, WB9GOJ.

"I've heard several mobile operators comment that the bright light behind the S-meter on the 13-509 sometimes makes night time driving difficult. Fortunately, the problem can be cured with a few simple parts. The original idea for the circuit appeared in a fairly recent issue of *73 Magazine*, but I cannot recall the author or the issue. My thanks and apologies to him!

The purpose of the circuit is to light the S-meter bulb only when a signal is received, or when the PTT button is depressed. To make life interesting, I decided to make the bulb glow green. This is accomplished by removing the grommet and bulb from the slot in the bracket behind the S-meter, and carefully removing the bulb from the grommet. Then insert the bulb into a green Cliplite LED lens, push the new assembly into the slot in the bracket behind the S-meter, and glue into place, if necessary.

The circuit can be wired on a 1″ × 1″ piece of perfboard. When complete, it may be covered with masking tape for insulation and tucked into the area behind the S-meter."

MECHANICS OF THE "J" ANTENNA

We give here the details for constructing a mobile "J" antenna, with an adaptation of his drawings. It's all self-explanatory. You can weld a stainless stub onto a 108″ CB whip, or have an auto shop do the job for you. The feed point selected is about 200 ohms, which is just right for hooking on a 50-to-200 balun. Dimensions will put you into the upper part of the 220 MHz band, close enough for local repeater work. The drawing to the left in Fig. 46-13 does not show that the shields of *both* pieces of RG-58AU are connected at top.

13-509 IMPROVEMENTS

The most popular 220 rigs used by almost everyone are the MIDLAND 13-509 or the CLEGG FM-76. These rigs have several things which can be easily changed, not to make them operate differently, but to make it easier to use them. They are presented here for your use.

The MODS do these things:

1. Provide for easy TT pad connection and use via the accessory plug.
2. Make it easy to connect a discriminator meter without tying up the accessory plug.
3. Eliminate a long dangling power cord.

The accessory socket as delivered has connections for mike, B+ during transmit only, and discriminator meter output. I move the discriminator output to a separate RCA audio jack, connect the PTT line in its place and switch the B+ wire to a point nearby that is "hot" all the time.

This allows powering the TT pad from B+ in the rigs. It provides for keying the rig automatically when pad buttons are pushed if the necessary

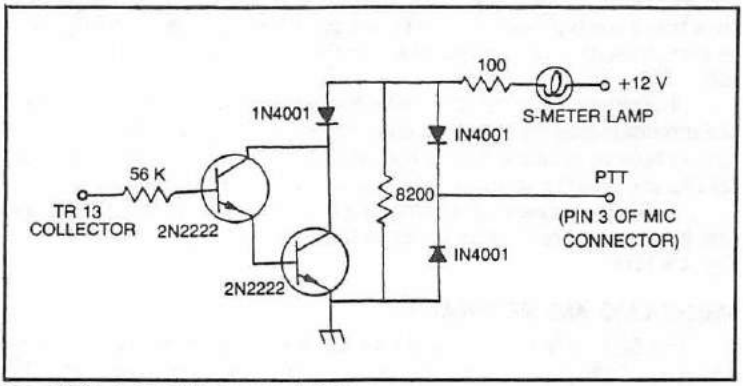


Fig. 46-12. A squelch-operated dial lamp.

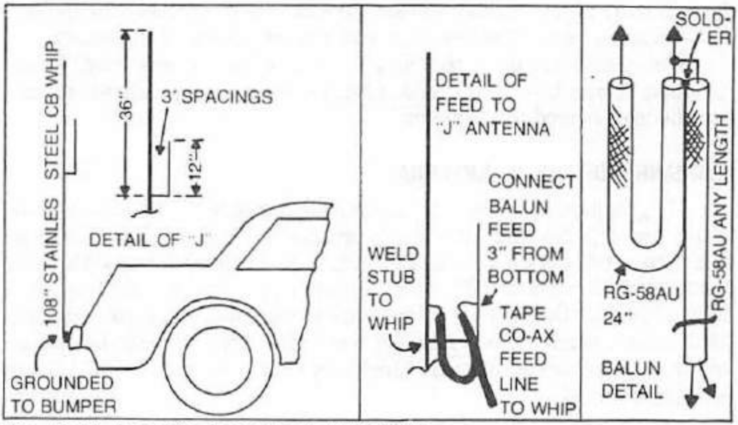

108" STAINLESS STEEL CB WHIP
36"
3' SPACINGS
12"
DETAIL OF "J"
GROUNDED TO BUMPER
DETAIL OF FEED TO "J" ANTENNA
CONNECT BALUN FEED 3" FROM BOTTOM
WELD STUB TO WHIP
TAPE CO-AX FEED LINE TO WHIP
SOLDER
RG-58AU ANY LENGTH
RG-58AU 24"
BALUN DETAIL

Fig. 46-13. A mobile J antenna for 220 MHz.

circuitry is incorporated in the pad, and it allows easy discriminator connection with any zero center sensitive microammeter or millivoltmeter for adjusting receive crystals to frequency. If you calibrate the meter you can also tell others how far off their transmit frequency is.

In addition, I move the fuse holder close to the chassis and insert a Jones 2 prong connector 8 inches from the chassis. This makes it easy to change the rig from mobile to base and vice versa and makes it a lot neater.

Following are steps to accomplish the mods: (All work is inside the rear relay compartment.)

1. Add RCA phono jack on rear adjacent to the power cord. (See Fig. 46-14A.) The small round single hole jack requires a ¼ inch hole. (Hint: drill a small pilot hole first and be careful not to drill into internal wiring harness.)

2. Remove violet wire from pin 4 of accessory jack and connect to RCA phono jack. (See Fig. 46-14B)

3. A grey wire goes from hole #12 on the PC board beside the relay and under the rear antenna connector, into harness across rear compartment. Cut the tie wrap that is in the middle of the harness and separate out the grey wire where it goes near the accessory jack. There is adequate slack that if you tug carefully it will reach pin #4 on this jack. Carefully strip off a small length of insulation and solder this wire to Pin 4. This is the PTT line.

4. Remove white wire from hole #10 beside relay on PC board (under the antenna connector) and feed around front side of board and connect to pad on bottom of board that is hot when power switch is on. (See Fig. 46-14C for drawing of under side of board.) This is the B+ change.

5. Shorten power cord by cutting 8 inches from chassis and placing fuse holder and 2 prong Jones plug on this lead. Put fuse in red lead. (See Fig. 46-14D.)

ANOTHER MIDLAND MODIFICATION

The MIDLAND 13-509 and CLEGG FM-76 are probably the most widely used 220 transceivers, due almost entirely to their being nearly the only ones available at bargain prices.

Over a period of over two years there have been evolutionary changes, but the basic rig has remained the same.

The purpose of this article is to detail a few of the most important of these changes. If you own one of the older rigs you might consider incorporating one or more of these changes in your rig. See Fig. 46-15.

I do not have the serial numbers at which the changes occured, so the best way of telling whether your rig has them or not is to take a look at the boards and see if the changes have been made.

Generally, if you have the old black case you will need them. One of the most needed changes was to replace the old wire contact relay with a relay with honest to goodness contacts, such as Allied Control T154-CC-12V. This has been done and all current brown and beige MIDLANDS have the new improved relay.

Other changes are as follows:

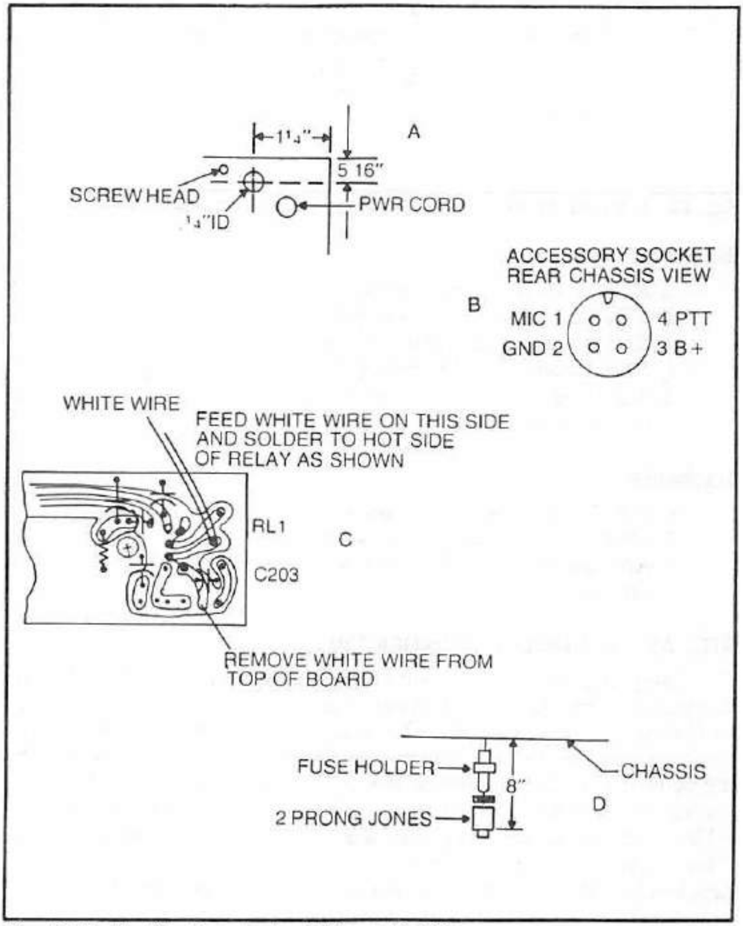


Fig. 46-14. Modifications to the Midland 13-509.

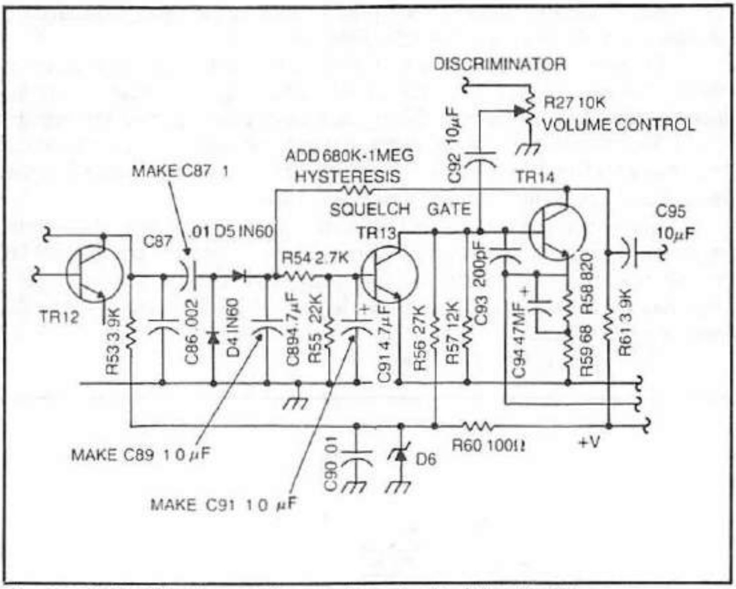


Fig. 46-15. Modifications to the receiver circuit of the 13-509.

Receiver:

1. R7 was 1K and is now 680 ohms.
2. C73 was .01 μf and is now .001 μf.
3. R45 was 47 ohms and is now 220 ohms.
4. Interchange C18, 2 pf with C21, 10 pF.
5. Add C122, 10 pF by cutting the PC board foil under L7 and jump the cut with this capacitor. (See Fig. 46-16.)

Transmitter:

6. Add 1.5 K resistor in series with blue lead to mike plug.
7. R103 was 22 K and is now 47 K.
8. Add under board TR26 a .001 μf ceramic capacitor B to E. (base to emitter)

STILL ANOTHER MIDLAND MODIFICATION

Greg Chartrand, WA9EYY writes in the *Hamletter* of the Wheaton Community Radio Amateurs that many hams find a problem of blown fuses or regulators when using their Midland 13-509's with AC supplies. The trouble arises from the alternator whine filter large capacitor-choke combination in the +12V line before the on-off switch. The heavy charging current which is drawn when you switch the rig "ON" creates a reverse EMF which can damage the power supply or its protective devices. Same thing happens (or can) when you switch "OFF". The solution to the problem is to shunt the choke (L-40) with a silicon diode (1N4002, 1N4005 or similar) with the cathode of the diode toward the fuse. This will suppress the reverse EMF and protect the protective devices.

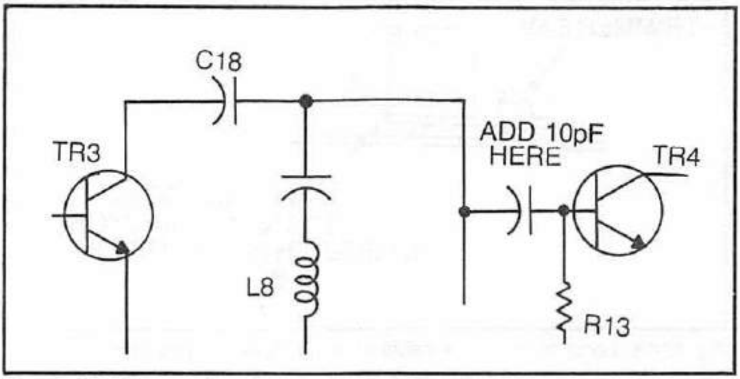


Fig. 46-16. More receiver improvements in the 13-509.

A 220 J ANTENNA

With the cost of everything going up, money-saving ideas are always welcome. If you can save money and increase radio performance at the same time, it is a double bonus.

The J-POLE antenna offers numerous advantages. It is omnidirectional, requires no ground plane, achieves a 6db gain over ¼ wave, and is easy and inexpensive to build. I have tested this antenna on 2 Meters against a Hustler Colinear type and found the J-POLE far superior as well as smaller. I also tested it on 220 MHz against a LARSEN ⅝ wave mobile antenna in a bad area of Spring Valley and on one repeater it showed an increase of over 3 units on the "S" meter.

The center conductor of the coax feeds the short element, shield to the long element. Matching is accomplished by varying, dimension "X", see Fig. 46-17.

The elements themselves can be made of stainless steel, copper rod, or simply telescoping radio antennas if you desire a collapsable model. Adjusting the antenna is most easily accomplished by using set screws through the aluminum block.

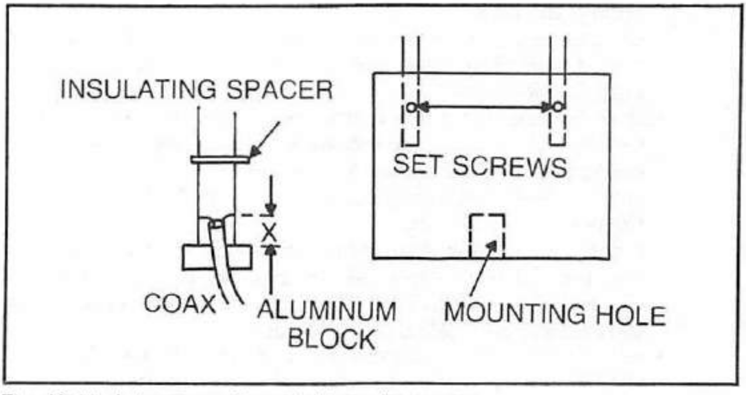


Fig. 46-17. A J antenna for portable or home use.

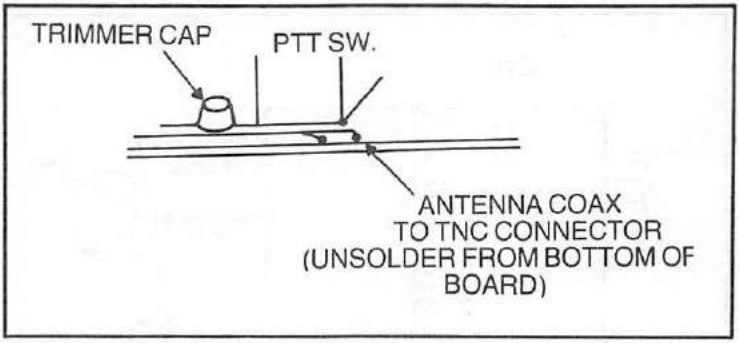

TRIMMER CAP
PTT SW.
ANTENNA COAX TO TNC CONNECTOR (UNSOLDER FROM BOTTOM OF BOARD)

Fig. 46-18. Location of coaxial cable to be unsoldered (Wilson HT).

Use of the following dimensions should get you to within a VSWR of 1.5:1 before any adjustments are made.

Long element - 38 ¾ inches
Short element - 12 ¾ inches
Feed point - 2 inches above block
Element spacing - 2 inches

BNC ANTENNA MODIFICATION FOR WILSON HTS

For some unknown reason, Wilson supplies their new model HTs with TNC antenna connectors. These threaded versions of the BNC are both hard to work with and hard to find . . . not to mention expensive. Changing the connector to a BNC makes antenna changing much easier, connectors are easier to find and adaptors are more available. It involves a little delicate work, though, and the purchase of a new "rubber duck" with, a BNC base.

Working space is tight at the top of the HT, but the following procedure has worked successfully on several HTs:

- pull out the battery tray, remove the screws in the back and bottom. Pull off the front of the radio, being careful, because it will be still connected by several wires to the battery holder and speaker.
- remove the screws from the board that hold the back on, and remove the back.
- unsolder and remove the center conductor only of the coax connected to the TNC connector. Leave the shield connected to the lug it is soldered to.
- the other end of that coax is attached to the PCB next to the PTT switch. Unsolder it on the bottom of the board and lift off both the center and the ground. See Fig. 46-18.
- remove the screw holding a bracket to the PCB. The screw is on the bottom of the PCB.
- remove the 4 screws from the top of the HT. The top plate should now pop out of the grey-colored trim, but just a little. Having unsoldered the coax by the PTT switch gives you just enough room to reach the nut holding the TNC base in place.
- unscrew the TNC retaining nut and remove the TNC base. (NOTE: braid of coax is still soldered to a lug from the lockwasher. This stays, and is used on the new BNC base.

- inset new BNC base, slide on lockwasher with lug and screw on regular net. Make sure nut is tightened securely, since there will be a twisting force on the base every time the antenna is connected or removed.
- replace 4 screws on top, and bracket screw from bottom of board.
- solder coax center conductor to center pin of new BNC base, see Fig. 46-19.
- replace back and insert screws.
- replace front and bottom and back screws.

CUTTING THE DUCK FOR 220 MHz;

The new rubber duck will have to be cut, as it is supplied to length for 2 meters. Measurements were made on the antenna supplied by Spectronics, by mounting the antenna on the side of a Bird wattmeter and cutting until an acceptable SWR was obtained. The 3½ inches holds for this model antenna only, and a different model antenna will probably require a different length. Measure per the diagram, Fig. 46-20, from the base of the duck's mounting stub after unscrewing it from the BNC. Cut the rubber with a razor blades or dykes, and either hacksaw the stiff copper of the antenna, or use a hefty wire-cutter. (The wire-cutter on a pair of vise-grips works well). Measure carefully—½ turn of the antenna's helix makes a major difference in the SWR.

Replace the rubber cap on the duck, screw it on the BNC, and pop the antenna on the HT. You're ready to go!

Materials Needed:

Amphenol UG1094 BNC Bulkhead Receptacle
Antenna Specialist "Rubber Duck" with BNC connector.

MODIFICATION OF SEARS, ROEBUCK CB MAGNET MOUNT ANTENNA

Sears sells a reasonably priced magnet mount CB Antenna which is easily converted to 220 MHz. The resulting ⅝ wave vertical works very well and costs about 1/3 the price of a comparable unit. The antenna sells for $14.50 in the catalog and $19.95 at Sears stores. It is marketed by Cascade Electronics, Timonium, Md. 21093; a division of Tessco, Inc. The Sears catalog number is 61G38411C. The unit is very well made, and

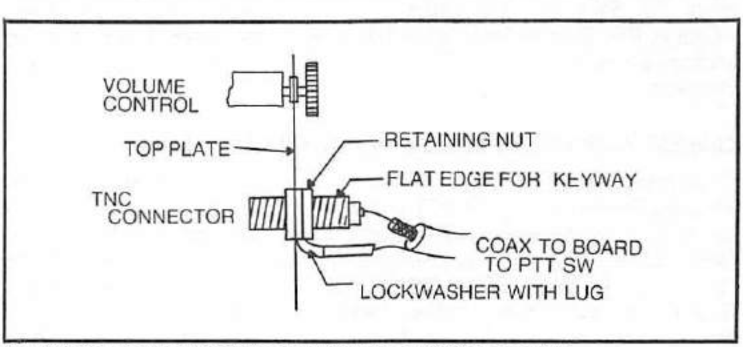


Fig. 46-19. Replace the Wilson TVC with a BNC connector.

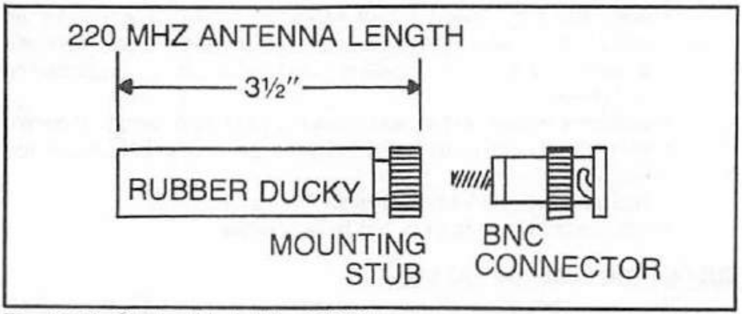


Fig. 46-20. Cut the "ducky" for 220 MHz.

features a soft aluminum bottom plate, a brass-ended coil form, a chrome plated spring and hefty stainless steel whip.

Referring to Fig. 46-21A, the four basic components are: (1) magnet base, (2) loading coil, (3) spring, (4) stainless steel whip. The two components which are modified are the loading coil (2) and the whip (4). The whip is cut down to 23-½ inches (597mm) by removing a piece of the large diameter end which fits into the spring assembly. The loading coil is more involved but can be performed with simple tools.

First, the outer plastic sleeve is removed to expose the base loading inductor. This is done by insetting a piece of pipe of the correct size to just fit inside the sleeve and contact squarely the outer conductor of the coaxial connector (a socket wrench works very well). A sharp rap with a hammer or the socket wrench will break loose the sleeve from the coil form. Unsolder and remove the existing coil and replace it with a coil made up of six turns of #14 buss wire. Solder the new coil at each end to the coil form (see Fig. 46-21C). Connect a 10pF disc ceramic capacitor between the feed-through and a point on the coil 1-¼ turns above the ground end. Do not replace the plastic sleeve yet. Assemble the coil, magnet base, spring and whip. The length from the base of the spring to the top of the whip should be set at 25-¾ inches (654 mm).

Check the SWR at 223.5 MHz. Small adjustments can be made by extending or retracting the ship section in and out of the spring assembly, and by moving the coil turns above and below the tap point closer or farther apart. The SWR should be under 1.5 to 1 as measured at the end of the length of RG-58 provided. If all is OK, replace the outer sleeve over the loading coil and reassemble. The modification of this antenna for 220 FM is complete.

CORRECT YOUR WILSON 2202SM HANDIE-TALKIE SCHEMATIC

While installing a PL deck in my Wilson 1-¼ meter handie-talkie, a minor error was made causing the +12-volt transmit B+ line to be shorted when the radio was completely reassembled. In troubleshooting the problem I found that the schematic diagram in the manual had several errors in the "power supply" section. Some of the errors are obvious; others are less so. If you own one of these radios, correct your manual as shown in the accompanying diagram, Fig. 46-22. Hopefully, you should never have to repair your radio, as they are constructed quite well. But if you make the mistake that I did, the corrections will speed up your analysis of what went wrong.

By the way, I had to replace the transmit transistor switch Q213. A substitute that has the same pin-out and the same physical size with adequate ratings is the GE-58. One final point: When working on the T2202SM, always cross reference the schematic with the parts list and the circuit board foil layout drawing. This will help you in detecting errors in the schematic that may still be lurking in your instruction manual. Thanks also to Greg, WA9EYY, for finding a couple of the bugs.

CORRECTIONS

1) Q213 is PNP transistor, not NPN
2) A cross-over connection dot is missing between S201 & R245, D208 and D206
3) R227, 220 ohms is not in the radio
4) S202b is labelled backwards
5) Wire from "hi" side of S202b to switched transmit B+ missing

LEGEND

1) Resistances are in ohms
2) Capacitances are in microfarads, unless specified otherwise
3) Corrections are as marked in number circles, keyed table at left
4) Wilson 2202SM manual, vintage early 1976

COMPACT PORTABLE EMERGENCY ANTENNA

You are driving in the country and you come across an accident. You yank out the handie talkie to call for help and—nothing! You are too far from the repeater, behind a hill, in a hollow, without enough power.

This is the situation posed by WA9VNJ, writing in *The Hamateur*, Wisconsin's area ham radio bulletin. Steve then goes on to describe a portable antenna originally described in *73 Magazine* and figured for 144 MHz. Such a portable antenna could give your rig just that extra reach that you need in an emergency, or for a pleasant week's operation from a country motel. We've adapted it for 220 MHz.

The confuguration is the trusty J-pole that Ye Editor recalls fondly from his early ham days, modernized and made cheap and dirty so that you can cling it together in ten minutes...or make a dozen and leave them behind as you travel. Looking at the diagram, Fig. 46-23, you'll see that the J is really two components—a ½-wave vertical plus a matching stub. It has a

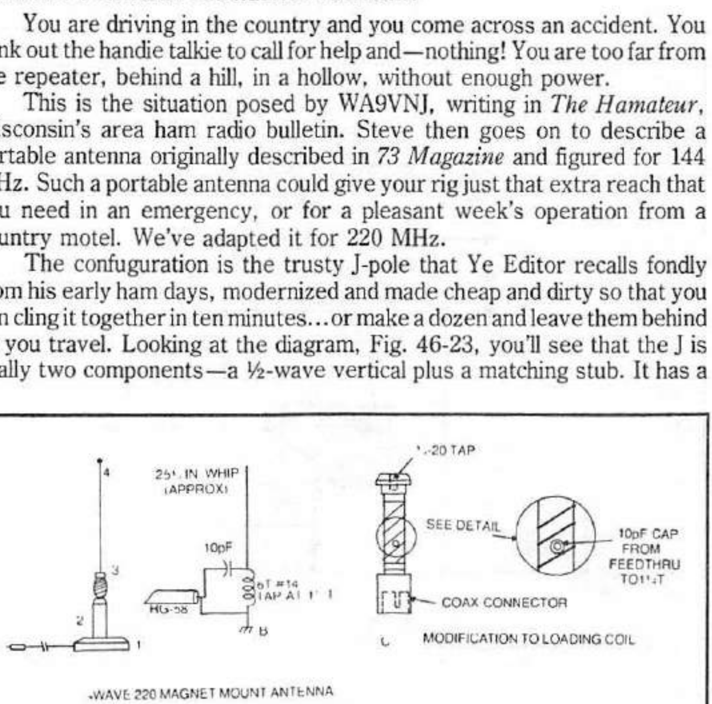

4
3
2
1
25½ IN WHIP (APPROX)
10pF
6T #14 TAP AT 1½ T
RG-58
B
-WAVE 220 MAGNET MOUNT ANTENNA
¼-20 TAP
SEE DETAIL
10pF CAP FROM FEEDTHRU TO 1½T
COAX CONNECTOR
C
MODIFICATION TO LOADING COIL

Fig. 46-21. Modifications to Sears Magnet Mount antenna.

low angle of radiation, just what we want to reach far-off repeaters instead of warming the sky.

Take a piece of 300-ohm Twin Lead approximately 37-38 inches long, and cut it as shown part way down the center of the plastic web, removing the excess piece of wire and trimming it to exact size. Leave a "bulge" in the top of the plastic for a hole to take a supporting cord.

The dimensions given in the diagram will put you at about 223 MHz. If you wish, you can start with some excess length at the top and prune for resonance, at the same time pruning the bottom for match to the coax line. In this case, WA9VNJ recommends pruning to the transmit frequency, making the point that we want the lowest possible SWR for transmitting; the receiver is a little more tolerant . If you prune, take it easy—an eighth or even a sixteenth of an inch at a time.

Connect a length of RG-58 co-ax to the bottom of the stub. Remember that you lose 7 db for every 100 feet of RG-58—keep the feed line short as possible! The connection to co-ax is the phsically-weak link in the system; our experience has been that soldering destroys the softness of copper (like the center conductor of co-ax) making it very brittle and prone to breaking as it is flexed. Careful use of plastic electrical tap here will reinforce the joint, and will provide some waterproofing.

Punch a hole in the plastic web at the top of the J and tie on a long piece of nylon cord. Attach a 3-oz fishing sinker to the free end of the nylon, heave

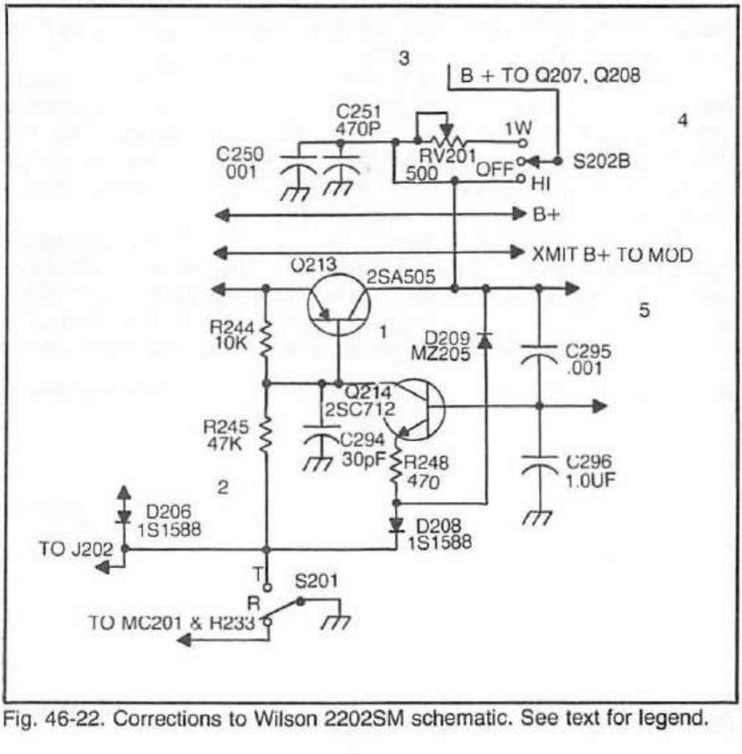


Fig. 46-22. Corrections to Wilson 2202SM schematic. See text for legend.

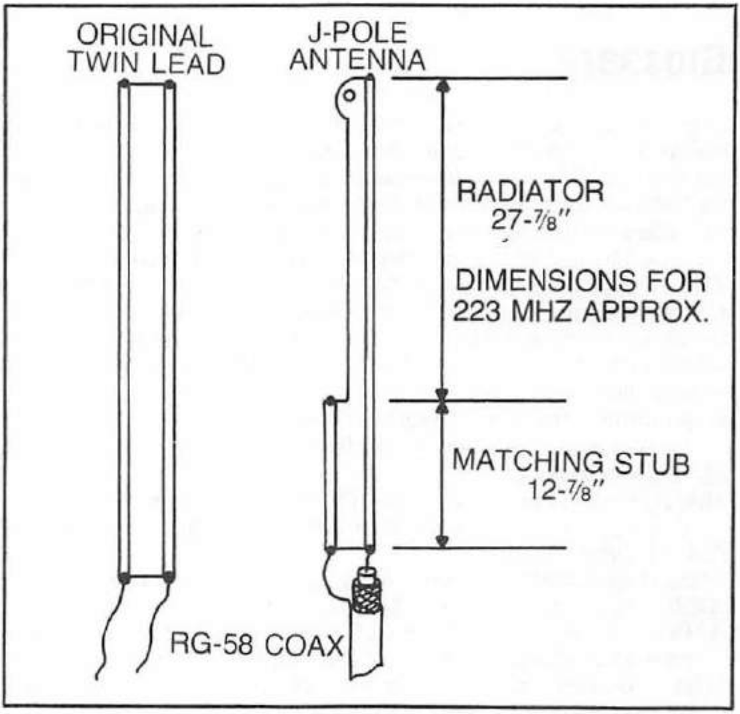


Fig. 46-23. A compact, portable emergency antenna.

it over a tree branch, haul away, connect the co-ax to your radio, and you are in business for improved contacts.

Authors Note: This design is good when you take your CLEGG or MIDLAND 13-513 to work—you can pull this antenna out of your pocket, and tape it to the window.

Glossary

Every special interest group seems to develop a language all its own. FM and Amateur repeater communication are no exception. Just as the HF operators and DXers have developed a language to suit their needs, so have the FMers. Obviously, many of these terms will be used in this text, so I have taken the time to prepare a glossary to help you understand the work to follow. Please spend the time to read it over now, and feel free to consult it if you happen to get stupmed along the way. Keep in mind that this is a glossary of terminology garnered from all over the nation. Not all terms are the same in every local. Therefore, some may seem new and strange, while others will be very familiar. Nontheless, some FMer or repeater enthusiast is using them somewhere . . .

acquisition—The point at which one can utilize the relay facilities of a given system on a minimal-signal basis.

af—Audio frequency.

alligator—1. Timeout timer, as "The alligator got you, so repeat all after____." 2. A repeater system that is all mouth and no ears.

AM—Amplitude modulation

ancient modulation—FMers' derogatory term to describe a-m.

ARRL—American Radio Relay League.

ASCII—Computer code (American National System for Computer Information Interchange, or more properly called ANSCII).

atlas—Sometimes called repeater atlas. A listing of all repeaters on a local, regional, national, or international basis.

ATV repeater—Amateur fast-scan television repeater.

audio—verbal intelligence.

audio processing—Preparing audio for transmission.

autopatch—Repeater and/or remote base intertie to a telephone system.

auxiliary link or aux link—The equipment and spectrum necessary to intertie receivers and/or transmitters using other than normal repeater channels.

backup—Spare equipment, such as a transmitter or receiver.

battery backup—Emergency power source.

base—1. Bottom part of an antenna tower. 2. Home station.

BASIC—A computer language often used in repeater control systems.

basket case—Nonrepairable equipment.

belt—Safety belt used in climbing towers or other antenna structures.

blab-off or blab-off timer—See timeout timer.

black label—Background color of serial tag found only on certain early Motorola Motrac radios.

B.O.—1. Symbol for broken. 2. Abbreviation of business office when referring to the telephone company.

boat anchor—Early vintage land mobile FM radio.

bootlegger—Unlicensed individual operating on the amateur bands.

bottle—High-power transmitting tube.

box—A repeater, remote, or other relay system.

brain—Controller or control computer.

bread—Funds with which to build or maintain a repeater system.
bug—A problem in a system.
bunny hunt—A hidden transmitter hunt for fun or for locating a jamming station. Also called a T-hunt or fox hunt.
burst—A single tone transmitted to access a repeater or a remote.
buzz box—Land mobile radio with a vibrator power supply.

cable—See coax.
calibrate—To set to frequency.
call—To try to make contact.
call-in—Dial in to autopatch.
capture—The ability of an FM signal to override all other FM signals into a receiver.
carrier trail—The length of a system carrier after all user transmissions cease.
cart—Type of tape cartridge used in voice identification machines.
cavity—Specially constructed high-Q tuned circuit.
CG or channel guard—General Electric nomenclature for CTCSS.
channel—Operating frequency.
charger—Device to recharge batteries for portable or hand-held transceivers.
chicken bandit—FMers' derogatory term for any Class D citizen's band radio operator.
chip—Integrated circuit.
clip lead—Jumper wire used for temporary connections.
clipper—Audio processing circuit or device.
clobber—To interfere with or be interfered with.
closed—A repeater, remote, or other system, with restricted membership and system access limited to only that group.
closet—Space alloted for a system at a repeater site.
club—Organized group of amateurs with a common interest.
cluge—Also spelled kluge. A breadboarded system.
CMOS—Family of metal oxide integrated circuits, known for low current drain and wide voltage range.
C.O.—Telephone company central office.
combiner—Device used to sum rf signals.
commercial—Land mobile FM service.
common frequency—Nationally accepted repeater or simplex channel.
compander—See clipper.
compresser—See clipper.
computer—1. Data processing device. 2. In repeaters, the controller if microprocessor based.
Com-Spec—Communications Specialists Corp., manufacturer of CTCS, burst and dual tone encoders and decoders.
coax—Transmission line to the antenna.
conditions—Atmospheric phenomena affecting communications.
control—System (peripheral) used to control repeater and/or remote base.
control station—FCC-licensed amateur radio operator designated by system licensee to oversee system operation.

coordinate—Obtaining approval of one's peer group in a given area to operate a repeater or remote base.

coordination committee—Same as coordinator, but functioning on a committee basis.

coordination council—Organization founded to give technical guidance to area coordination efforts, and to act as a collective political voice for the repeater-oriented amateurs of a given area.

coordinator—Individual selected by the amateurs of an area to assign repeater and remote base channels.

cop—Overzealous control station.

COR—Carrier-operated relay.

cord—1. AC line. 2. Antenna guy wire.

COS—Carrier-operated switch.

counter—Frequency counter.

C.P.—Circularly polarized antenna.

CPU—1. Abbreviation of central processor unit. 2. Computer.

crest—The top of a hill or mountain where a repeater or remote base site is located.

crimp—Solderless conector that is not recommended for rf at VHF or UHF.

crispy-crittered—A piece of FM communications equipment that has suffered smoky technical failure.

crocodile—System that has an overpowering transmitter.

cross-link—To interlink one system to another, or to a secondary site.

cross-mode—Listening and transmitting via FM, but retransmitting and re-receiving in some other mode.

crud—FMers' slang for QRN (static), QRM (interference), noise, etc.

crystal—Piezoelectric device used for frequency control.

CTCSS—Continuous tone coded squelch.

CTS—See CTCSS.

DC—1. Abbreviation of direct current. 2. FMers' derogatory term for all non-FM high-frequency amateur operation.

DC power supply—Electrical source for system operation.

decoder—Device which converts signalling tones to operational functions.

deemphasis—Process of restoring audio to its original characteristics.

demographics—Location of usership in relation to system and system coverage.

dense—FM operator who cannot, or refuses to, learn and use proper FM operating techniques.

desense—Slang for desensitization.

desensitization—Loss of receive sensitivity caused by rf leakage into the system receiver from the system transmitter.

destinate—Arrive at a given location.

dev—Slang for deviation.

deviation—FM modulation technique.

dial—Control, or to initiate telephone calling sequence.

diamond—System that exhibits long-term, failure-free performance.

direct—Simplex.

discriminator—A form of FM detector.

dispatcher—1. A Motorola radio. 2. A person who assigns work via two-way radio.

dog—A piece of gear that continually suffers failure.

downlink—Radio connection from the site of a system to another location for control.

DTL—A family on integrated circuit logic before and superseded by TTL.

duck—A flexible helical antenna for hand-held transceivers. Also called rubber duckie.

duplex—Individual station that transmits and receives simultaneously.

duplexer—Device which permits simultaneous transmission and reception with one antenna.

Dural—Tradename for a type of aluminum pipe used in some antennas.

duration—Time interval.

electric—any power source, whether AC or DC.

electric talking box—Repeater or remote base.

elephant—A system that is all ears and no mouth.

emitter follower—Impedance-conversion circuit using active semiconductor devices.

encoder—Tone generating device used for some aspect of system access or control.

envelope—1. Tube. 2. Modulation characteristic.

ERP—Abbreviation of effective radiated power.

evict—Loss of the site of a repeater or remote base site.

excuse—A tall tale told by a system owner to users as to why system is inoperative.

exit—To leave a contact.

extender—A noise blanker option for Motorola low-band radios.

false or falsing—Not responding to command, or initiating wrong function.

farm—Antenna structure with many antennas on it.

FCC—Acronym for Federal Communications Commission.

FET—Abbreviation of field effect transistor.

filter—Device to eliminate unwanted signals.

flake—Southern California FMers' derogatory term to describe a poor operator.

fly—Individual who enjoys tower climbing.

flying radio—A transmitter with wandering spurious output. Also called a flying transmitter.

FM—Abbreviation of frequency modulation.

fone—FMers' slang for autopatch.

frequency—Specific spot on which to transmit and receive.

fried—Equipment that has failed and burned.

front end—Rf and first mixer stages in a receiver.

FSM—Abbreviation of field strength meter.

full quieting—Totally eliminating any background noise in FM reception.

fun mode—FM (coined by *73* magazine publisher Wayne Green).

fuse—Electrical protective device.

gain—Antenna or amplifier characteristic.

gallon remote—A remote-base system operating at maximum legal power.

garbled—Distorted audio.

GE—Noted land mobile radio manufacturer. The following GE tradenames have become common terms in amateur circles: Mastr /pronounced master), Mastr Professional (Mastr-Pro), Master-Executive (Exec), Mastr II, Mastr Royal, Progress-Line, Pocket-Mate, PR, PE, Channel Guard, Custom MVP, Porta-Mobile, TPL. Both PR and PE are hand-held units.

generator—1. Electronic test instrument used to produce af or rf signals. 2. An emergency power source.

green—Funds necessary to build, install, and maintain a system.

green box—25-watt military amplifier manufactured Motorola Corp.

gripe—User complaint to a system owner about the operation of the system.

GRONK—Early interlinked repeater/remote system in the United States West.

gross—A comment made over a system that others feel is in poor taste.

group—Amateurs who band together to install, operate, and maintain a system.

grunge—Interference.

guest—Non-member invited to operate a system.

gun—1. High-power transmitter. 2. High-power individual station.

ham—Licensed amateur radio operator.

handie talkie—Motorola tradename for a hand-held transceiver.

hand-held—Modern portable transceiver.

hang-in—A timer used to keep a system transmitter on for a preset time period after a user unkeys the transmitter. Also called a hang-in timer.

hard line—Special type of transmission line, especially suitable for VHF and UHF operation.

hardware—System equipment.

heavy—An interesting conversation or contact.

Heliax—Tradename for a special transmission line.

helical—Resonator design.

hell—User-caused operational problems on a repeater.

hernia talkie—Old tube-type portable transceiver.

hetrodyne—To convert or change frequencies by a mixing action.

high band—The part of the radio frequency spectrum extending from 132 MHz to 174MHz.

hog—A repeater user who takes more than his fair share of the system time.

hole—Spectral space onto which one establishes a system.

house—Repeater site.

HR Report—Weekly amateur radio newsletter, printed and distributed by Ham Radio Publishing Group, Greenville, NH.

HT—Abbreviation of handie talkie.

hub—The central site of a multisite system.

idiot—1. A repeater builder who receives no wages. 2. A channel jammer or hog.

I-F—Intermediate frequency.

ill—Poorly performing system.

IMD—Abbreviation of intermodulation distortion.

IMTS—Acronym for improved mobile telephone service, which superseded MTS.

input—1. System receive channel. 2. Control data.

interference—Unwanted signal heard in system receiver.

intermod—Abbreviation of intermodulation distortion.

intermodulation distortion —Spurious signals heard in a receiver.

IRC—Abbreviation of international reply coupon.

isolator—Device used to isolate two or more transmitters from each other.

jammer—Someone who causes willfull and malicious interference to normal amateur radio communications.

jig—Homebrew setup for bench testing of a system.

jug—1. Cavity resonator. 2. Transmitting tube. 3. Cathode-ray tube.

jumper—A wire run between two points.

ker-chunk box—A very basic repeater.

kilowatt—A transmitter running at 1000 watts DC input power to the final amplifier.

king—FMers' derogatory term used to describe certain system owners.

K.I.S.S.—Acronym for "keep it simple, stupid," which FMers have taken from the computer field.

kit—All parts necessary to assemble a repeater or remote base system.

kW—Abbreviation for kilowatt.

lamp—1. Pilot light. 2. Vacuum tube.

land mobile service—Commercial communications service using FM technology.

lane—A poor quality road to a repeater site.

law—FCC monitor station.

LCD—Abbreviation of liquid crystal diode.

LD—Series of RCA hybrid radios for the land mobile service.

league—Nickname of the American Radio Relay League.

leakage—Rf escaping from confinement.

lean—Insufficient funds to meet operations costs.

lease—Repeater site rental agreement.

LED—Abbreviation of light-emitting diode.

licensee—Holder of system license.

lid—A poor operator.

limiter—Receiver stage used to remove any AM component.

limiter meter—Indicator of the amount of current drawn by a limiter stage.

line—Antenna lead.

linear—Type of amplifier operation.

linear IC—Integrated circuit designed for use in analog applications.

linear translator—A repeating device that does not detect signals before retransmission and can repeat all modes.

link—Interconnection between a receiver and a transmitter in a system.

local control—On-site control of a system.

local oscillator—A stage used in receiving or transmitting converters.

lockout—Device used to prevent repeater operation when a carrier is present on the output channel.

LOS—Abbreviation of loss of signal.

low band—The part of the radio frequency spectrum extending from 30 MHz to 50 MHz.

machine—Any relay device.

magic—Commodity needed to make a system operate to desired specifications.

magic box or magic talking box—Repeater or remote base.

maniac—Foul-mouthed jammer.

mast—Pole which supports antenna.

Mastr—Series of General Electric land mobile FM radios.

max—Abbreviation of maximum.

Metrum—Motorola 2-meter transceiver.

mic—Abbreviation of microphone.

micro—1. Abbreviation of microcomputer. 2. Abbreviation of microprocessor.

microprocessor—Minicomputer.

mil-spec—1. Abbreviation of military specifications. 2. Term used in government surplus equipment descriptions.

min—Abbreviation of minimum.

mixer—Receiver or transmitter stage that combines two signals and produces the sum and difference of both.

mob—Uncontrolled system usership.

mobile—Station installed in and operated from a moving vehicle.

mobile extender—Mobile remote base.

modulation—1. Act of imposing audio on the rf carrier. 2. Audio level.

mole hole—A repeater or remote base on undeveloped land.

Motorola—Noted land mobile radio manufacturer. The following Motorola tradenames have become common terms in amateur FM circles: Micor, Motrac, Mocom, Motran, Research Line, Transistorized Research Line, PL, and HT.

mount—Antenna support hardware.

MSS—Abbreviation of Motorola service station, meaning one that is authorized for repair of two-way radios.

MTS—Abbreviation of Bell System's Mobile Telephone Service.

multi-site—System that utilizes two or more locations.

narrow band—System operating with narrow transmit deviation and narrow receive deviation acceptance, generally 5 kHz, but subject to local interpretation.

national plan—Nationally adapted bandplan for repeater and other operations.

nest—A mountaintop repeater or remote base site.

ni-cad—1. Abbreviation of nickel-cadmium type batteries. 2. Capitalized, it is the tradename of Gould.

night owl—See owl.

noise—1. Hiss. 2. Static. 3. Incoherent babble.

normalize—To return a system to its usual operating condition.

OM—Abbreviation of amateur term old man.

omni—Antenna that radiates in all directions.

open—Repeater operation for use by any amateur who legally may and can access the system.

OSCAR—Acronym of orbiting satellite carrying amateur radio, which is actually a SSB/CW crossband repeater in Earth orbit.

oscillator—Frequency generating device or circuit.

oscilloscpe—Piece of test equipment for view waveforms.

outsider—Unwanted intruder on a closed or private system.

oven—Container for holding and heating piezoelectic crystals to maintain frequency stability.

owl—Late-night control operator of a system.

pad—Touch-Tone R encoder.

pan—To avoid use of a given system.

parameter—1. Specific guideline. 2. Operating condition.

pass—Regulator transistor.

patch—Abbreviation of autopatch.

PC—Abbreviation of printed circuit.

PE—General Electric hand-held series.

peripheral—Equipment not directly essential to the relay capability of a system.

PET—Commodore Corporation microcomputer trademark which is very popular in amateur repeater control systems.

pirate—Uncoordinated repeater or remote base.

PL—1. Motorola Corporation trademark for its CTCSS system. 2. Abbreviation of private line.

PLL—Abbreviation of phase-locked loop.

PM—Abbreviation of phase modulation.

polarization—The direction of the electrical component of a electromagnetic wave, such as a radio wave, which is often used in describing antennas.

power—1. Electrical supply to a system. 2. Generated and transmitted rf.

power supply—Device that converts AC mains power to the power operating requirements of a system.

PR—General Electric hand-held series.

preamp—Rf amplifier placed ahead of a receiver to improve sensitivity.

preemphasis—Preparing audio for transmission.

Pre-Prog—Abbreviation of Pre-Progress, an early line of General Electric tube-type land mobile FM radios.

private—A repeater or remote base with a selective membership and not open to others.

Prog—Abbreviation of Progress, a second-generation line of General Electric land mobile FM radios.

QC—1. Quality control check. 2. Abbreviation of Quiet Channel, an RCA Corporation trademark for its CTCSS system.
QRM—Man-made interference.
QRN—Natural interference, or static.
QSO— On-the-air contact.
quad—Type of parasitic antenna.
quadrature detector—A form of FM detector.
quarter K—Commercial 250-watt or 330-watt power amplifier.

radio—California FMers' term for any FM transceiver.
rap—Conversation or contact.
RCC—1. Abbreviation of radio common carrier, such as commercial paging and mobule telephone services. 2. Abbreviation of ARRL's Rag Chewers Club.
rcvr—Abbreviation of receiver.
real estate—Repeater site.
regulator—Device or circuit to hold voltage constant under different current loads.
relay—1. To continue communication through retransmission. 2. Electromechanical switch.
relay device—1. Repeater. 2. Remote base. 3. Translator.
relay system—1. Repeater. 2. Remote base.
remote—See remote base.
remote base—Amateur radio base station that is individually owned and operated, and is remotely controlled.
repeater—Radio relay device, mostly used for FM communications.
repeater atlas—See atlas.
Repeater Bulletin—Early amateur radio repeater advisory newsletter published by Wayne Green, W2NSD.
restricter—An autopatch circuit that limits dialing to prefix or geographic area to eliminate toll calls.
rf—Abbreviation of radio frequency.
rig—Station.
robot—Remote transmitter or receiver.
rock—Piezoelectric crystal.
ROM—Read-only memory.
rover—FM operator who wanders from repeater to repeater, supporting none financially.
RTV—General Electric trademark for self-curing silicone rubber sealant.
rules and regs—FMers' term for part 97 of the FCC rules and regulations, the part that governs the amateur radio service.
rx—Symbol for receiver.

scanner—Device that provides automatic monitoring of many frequencies in a preset order or sequence.
service—To repair a system.
service area—Coverage area of a system.

service call—See service.

shift—1. To change operating frequency. 2. Time devoted by control operator.

sign—1. To leave or end a contact. 2. Abbreviation of call sign.

simplex—Direct communication using one frequency for both transmitting and receiving.

single site—System operating from only one location.

site—System location.

slope—I-F curve in receiver.

smoke test—First test of an assembled system or other electronic apratus.

spec—Abbreviation of specification(s).

speech processing—Preparing audio for transmission.

split site—System with receiver and transmitter at different locations.

squelch—Receiver circuit that turns off audio when no station is being heard.

squelch tail—Noise burst emitted by a repeater between user transmissions.

squirrel—A transmitter, receiver, or crystal that will not stay on channel.

SSB—Abbreviation of single sideband.

SS quack—FMers' derogatory term for SSB operator and SSB operations.

standard—Abbreviation of frequency standard.

station blaster—FMers' term for Stationmaster antenna

Stationmaster—Very popular Phelps-Dodge Corporation base station, repeater, and remote base antenna.

steel—FMers term for the mast or tower used for antenna mounting.

surplus—Military or commercial land mobile FM equipment that is no longer needed by either service.

sweep generator—An FM alignment instrument.

synthesizer—Device to replace piezoelectric crystals which offers similar stability and full-band, channelized coverage.

tech committee—1. Group of amateurs responsible for installation and maintenance of a relay device. 2. Group of amateurs performing voluntary coordination efforts.

test—Evaluation of system equipment.

telco—FMers term for the telephone company.

ten codes—Land mobile number-coded system used on many Southern California area repeaters.

three-leegged fuse—Transistor.

T-hunt—See bunny hunt.

timeout timer—Device used to limit the length of user transmissions.

timer—Device that measures a given time interval and then actuates a given circuit.

tone—Audible signal.

tone access—Systex use requires tone transmission.

tool—Plastic alignment tool.

Touch-Tone®—Bell System trademark for a two-tone signalling/telephone dialing method.

TPL—General Electric Transistor Progress Line of two-way FM radios.
T-power—Tube-type radio with a transistorized power supply.
transcient—Non-resident amateur visiting and operating in another location.
transformer—AC-coupling device.
transistor—Bipolar semiconductor.
transmission line—Line from system to antenna.
transmitter—Device for generating and emitting rf signals
trustee—Holder of club license or club repeater license.
TTL—Family of integrated circuits employing transistor-transistor logic.
tube—Thermionic device for use in such activities as amplification, regulation, and rectification.
tune-in—An amateur gathering to adjust station equipment.
TVI—Abbreviation of television interference.

UHF—Abbreviation of ultrahigh frequency.
UJT—Abbreviation of unijunction transistor.
ultrasonic—Frequencies above the audible range.
Uncle Charlie—Slang for FCC.
unidirectional—Transmission in only one direction.
unit—A portion of a system, such as a receiver or a transmitter.
uplink—Link from a control point to a repeater or remote base.

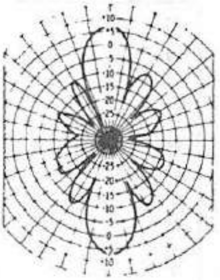
varactor—Variable capacitance diode.
vault—Repeater site.
vertical—An antenna with vertical polarization.
VHF—Abbreviation of very high frequency.
vintage—Old tube-type equipment.
voter—Device to automatically select one of many receivers in a large system.
VRAC—ARRL's VHF Repeater Advisory Committee.
V-RX—WWV receiving facilities in a system.
VSWR—Abbreviation of voltage standing wave ratio.
VUAC—ARRL's VHF-UHF Advisory Committee.

watt—Unit of power.
Westlink—Amateur repeater on-the-air news service produced weekly in Los Angeles, CA, by the Westlink Radio Network.
wetbox—A repeater on a boat that is used mostly by maritime mobile stations.
whistle-up—A tone access system responsibe to human whistles.
wideband—A transmitter designed to transmit and receive with deviation acceptance of greater than 15 kHz.
wireline—A technique of interconnecting two sites in a split or multisite system.
wireline control—A technique of system control in which control is maintained from fixed sites via wires.
WR—Special repeater call signs no longer issued or renewed.

XMTR—Symbol for transmitter.

Appendix

Solutions to Channel Interference



The following two papers were written by Mr. Robert O. Thornburg, WB6JPI, and deal with the problems inherent in implementing 15-kHz tertiary channel spacing. They are herein reprinted with the permission of the Two Meter Area Spectrum Management Association of Southern California (Formerly the Southern California Repeater Association).

Paper I describes the problem in depth, while Paper II details some solutions which have now been proven in Southern California and elsewhere. It is hoped that this information will be of help to areas now reaching the point of total 30-kHz system occupancy, and considering the implementation of 15-kHz tertiary channels.

1.0 *Introduction*

This brief note points out the adjacent-channel problem when using 15 kHz separation.

2.0 *Discussion*

The splatter between channels with 15 kHz splits (split-splits) is a major problem. One transmitter will cause interference to a receiver tuned to the adjacent channel. The major point of this note is that this interference will occur no matter how well the receiver is designed. Do not blame adjacent channel splatter on a poor receiver (although it is aggravated by this condition). It is an inherent problem in the transmitter.

Figure A-1 shows the transmitted spectrum for an FM signal having 5-kHz peak deviation. The three spectrums are calculated for 2, 3 and 4 kHz modulating sine waves. Note that the bandwidth of this signal does not just stop at ± 5 kHz (the peak deviation), but goes on forever. A receiver with an ideal filter tuned next to this signal will get some sidebands (splatter) in its bandpass.

Figure A-2 shows the problem for a 30-kHz and 15-kHz split. The degradation to the 15-kHz spacing is 60 dB in splatter, a major problem. How nice that the SCRA restricted this problem (on the most part) to be dealt with between repeaters by using the reverse-split concept.

The modulation characteristics of repeaters must be optimized to reduce to a minimum the adjacent channel splatter. The deviation and pre-modulation must be controlled.

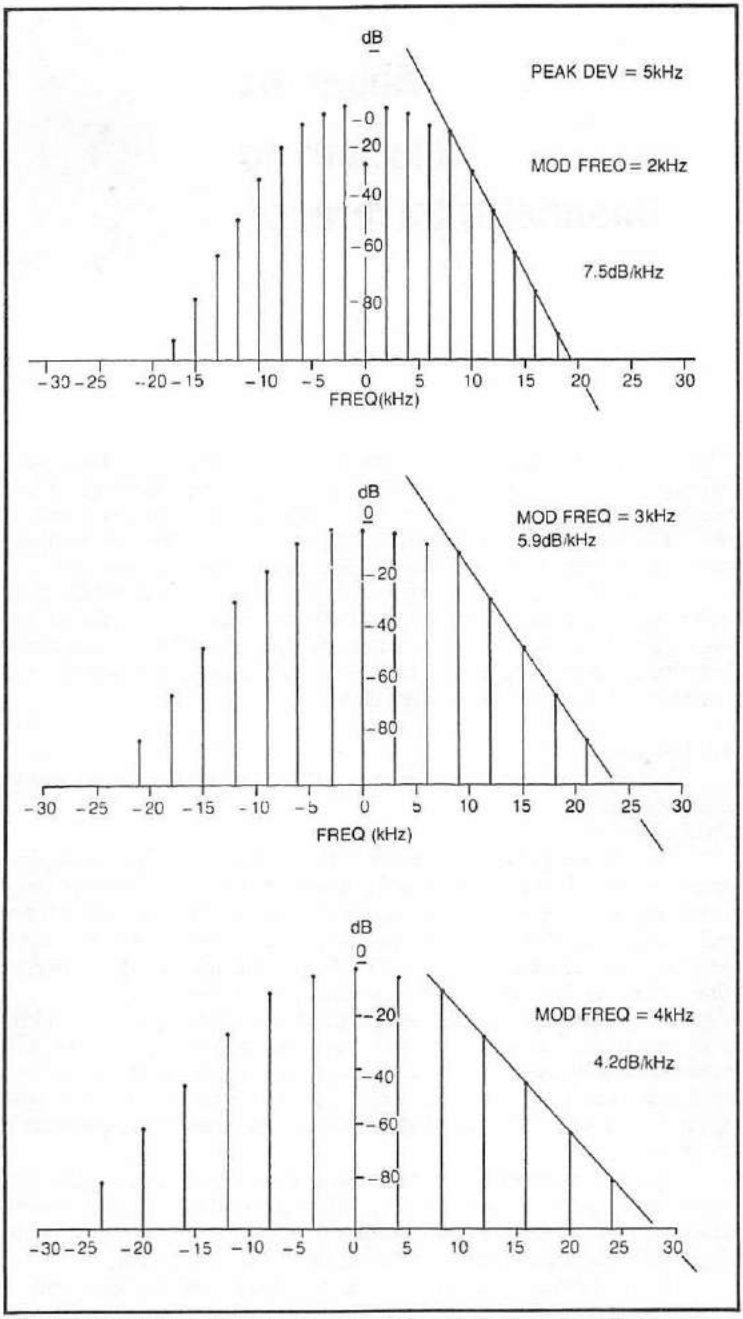


Fig. A-1. FM sideband distribution with 2, 3, and 4-kHz modulation.

The FCC recognized this problem and in parts 87 and 89, and recommends wording like:

> Each repeater shall be provided with a device which automatically prevents peak deviations in excess of ± 5 kHz. The transmitter shall also contain a low-pass filter between the modulation limiter and the modulated stage and, at audio frequencies between 3 kHz and 20 kHz, shall have an attenuation greater than the attenuation of 1 kJz by at least
>
> $$60 \log_{10} (f/3) \text{ decibels}$$
>
> where f is the frequency in kilohertz. At audio frequencies above 20 kHz, the attenuation shall be at least 50 decibels greater than the attenuation at 1 kHz.

Source: Vol. V 87.73 p. 17
Vol. V 89.109 p. 70

This will not eliminate the problem; only keep it minimized as much as possible.

15-kHz Repeater Spacing

Bob Thornburg, WB6JPI
May 24, 1976

Introduction

When two meter FM started, it was based upon conversion of available commercial equipment. This equipment used 15 kHz (peak) deviation and the receivers were configured for 60 kHz channel separation. The commercial mobile-radio bands became crowded, and to increase their channel capability the active 2-way industry changed to "narrow band" with 5 kHz deviation and 30 kHz channel spacing. This change really started a boom in Amateur FM due to the availability of low cost "wide band" equipment now outmoded by industry. But, the Amateurs soon realized that the wideband radios took up a lot of room, and by the time of Docket 18803 (August 1972), most amateur systems were using 5 kHz deviation and 30 kHz channel spacing on 2 meters. The generally accepted "band plan" for 2 meter FM is now based upon 30 kHz channel spacing.

The 2 meter repeater band was quickly saturated in many areas, with all 27 30-kHz repeater channels occupied. Additional repeater channels could not be obtained outside of the 146-148 MHz range, so the split-split, or 15-kHz channel spacing evolved. Note that the name "split-split" is due to the splitting of the original 60 kHz spacing first to 30 kHz, and again to 15 kHz. The 15 kHz spacing is also called tertiary channels by the same logic.

There exists some psychological hang-up with tertiary channels. They are, in themselves, just the same in bandwidth performance, etc., as the 30-kHz channels between which they are wedged. The purpose of this paper is to discuss the problems surrounding 15 kHz channel spacing and to make it perfectly clear that the problems are due to the spacing, and apply to all channels whether they are "60", "30", or "15" kHz channels. See Fig. A-2.

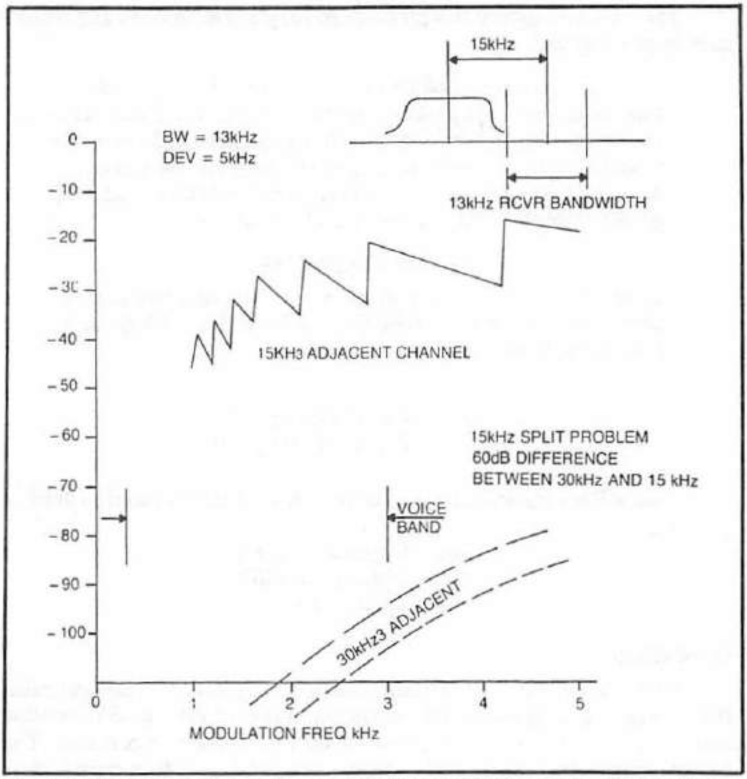


Fig. A-2. Showing a 60 dB difference between 30-kHz and 15-kHz spacing.

History

My first entry into the world of split-splits was when I was president of the Mount Wilson Repeater Association. The Southern California Repeater Association (SCRA) is our local coordinating council, and in 1974 they expressed a need to coordinate repeaters to 15-kHz channels. Burt Weiner, K6OQK, licensee of WR6ABE, the Mount Wilson repeater, suggested (convinced) me that the 15-kHz assignments should be reversed from their adjacent channels. This concept was brought forth and argued for by me, and the SCRA became the first coordinating group to recognize the significance of reverse split-splits. Presently, the SCRA has 21 repeaters on 15-kHz channels, with 3 "non-inverted," and 18 reversed.

Modulation Spectra

Now for some technical discussion of the problems with 15-kHz channel spacing. First, let's look at the spectrum out of an FM transmitter. By the very nature of FM the theoretical spectrum is infinite. Unlike A-M, the FM sidebands go on forever. Luckily, they get very small very fast after a certain bandwidth. This bandwidth is defined by "Carson's Rule" as

$$B_t = 2\,(f/W + 1)\,W = 2f + 2W$$

where:

f is the modulating frequency
W is the deviation

For example, say the upper tone (1633 Hz) of a 16-button Touchtone is deviated 5 kHz. The resulting bandwidth would be 13.3 kHz. Now look at voice over the 300-3500 Hz range. If the modulating signal produced 5-kHz deviation at 3500 Hz, the resulting FM bandwidth would be 17 kHz, well in excess of a 15-kHz channel. Unless your voice is very squeaky, most of the energy is concentrated around 900-1000 Hz, with very little (but very important for intelligibility) above 1500 Hz. The net result is that, for voice operating with 5-kHz deviation, most of the FM signal is contained in a 12-kHz band.

But voice is not all that comes out of a repeater. There are MCW ID, clicks, snaps, and the horrible SQELCH TAIL. Yes, the squelch tail. This is a burst of wideband noise equal to half of the receiver's I-F bandwidth, and can have quite large high frequency components, particularly if the de-emphasis-pre-emphasis circuits in the receiver-transmitter are not matched.

Modulation limiters do not help this problem much. Sure, they hold the peak deviation to 5-kHz, but for high modulation frequencies we have already shown the FM spectrum to exceed the channel width with the deviation limited to 5 kHz. So limiters, compressors, levelers, etc., are not the answer. Some solutions are presented later but first let's look at the receiver.

Receiver Bandwidth

From the last section we have a 12-kHz bandwidth of modulation to receive. Now the transmitter frequency may be off a little and/or the receiver may drift so repeater receiver's bandwidth must be somewhat larger than 12 kHz. If the transmitters can drift, say, ±500 Hz and the receiver ±500 Hz, then the receiver acceptance band should be 14 kHz. These stability figures are tight for present day repeaters and users, but they still illustrate the point. The receiver must separate the desired 14-kHz signal from the adjacent 14-kHz signal located only 15 kHz away. This allows the I-F filter in the receiver only 2 kHz to obtain significant rejection. How much is significant? A mobile operating 10 watts at 5 miles from the receiver will produce an input signal of 700 microvolts (−50 dBm). If this signal was on an adjacent channel of a receiver having 0.5 microvolt sensitivity (−113 dBm), the required rejection would be 63 dB. At 50 miles, the same mobile would only require 43 dB rejection. The latter case (50 mile) would require a 10-pole filter and the 5-mile case cannot be solved with any practical filter.

So it is very clear that 15-kHz channel spacing is impossible. The mobile communication industry has stated numerous times in their publications, IEEE, and before the FCC, that 20-kHz spacing for 5-kHz deviation is marginal, and anything less is foolish. The latest band to be formally channelized is the marine VHF band, which has 20-kHz spacing. Also, be aware that the 15-kHz spacing is unique to 2 meters. (We have already split 220 to 20 kHz and 450 to 25 khz spacing. To consider splitting them to 12.5 or less, even I think is foolish.)

Intermodulation

Before we get to how to make 15-kHz spacing work, let's look at another receiver characterisitc, intermod. An equation giving the magnitude of the third order intermodulation product is

$$IM3 = 7 + 2A + B - 60 \text{ LOG } (f_A - f_B)$$

where:

$IM3$ = magnitude of 3rd order in dBW
A = signal input of nearest frequency transmitter, in dBW
B = signal input of other transmitter in dBW
f_A, f_B = frequency of interfering transmitters in MHz

Note that the intermod level is a strong function of the spacing ($f_A - f_B$). For example, consider two mobiles each located 5 miles from the receiver, and each radiating 10 watts. One is transmitting 30-kHz from the receiver input, and the other 60 kHz (30-kHz spacing). The resulting 3rd order interference would be −112 dBm, or about 0.5 microvolt; not something to worry about. Now let those two mobiles be at 15 kHz and 30 kHz from the receiver (15-kHz spacing). The interference level increases to −94 dBm or about 5 microvolts. Now you can worry. The intermod is 18 dB worse.

So where are we? First, we clearly showed that you can't keep the adjacent channel out of your receiver, and that the intermod is 18 dB worse than it was written 15-kHz spacing. Looks hopeless, doesn't it? Amateurs have pushed communication concepts before, and we can still do it. 15-kHz spacing can work; let's see how.

Priority

First, let's establish some priorities. To do this we divide the world into two classes: repeaters and users. Repeaters generally sit on high places and provide service to many users, mostly in low places with low(er) power. Since the repeater is a single channel serving many users, it should be protected as much as possible from interference. It should have priority.

If anyone can control interference by having the best equipment, the repeater can. Other constraints on the repeater such as reliability, inaccessibility, and performance, all warrant a higher class of equipment than the constraints placed on the user. The repeater can usually afford better equipment. So the repeater can best beat the interference problem. The repeater should be given all possible help to maintain a usable level of interference.

Reverse Splits

No matter how good the equipment in the repeater is, it can't stop interference from a transmitter that is trying to operate the adjacent

15-kHz channel and is 1.5 kHz off channel, or is deviating 10-kHz (or even 7-kHz). If the interfering stations to your repeater are users, then the situation is very difficult to control. For instance, if two repeaters, each having 100 users, are 15-kHz apart, and not reversed, then the adjacent channel interference on each repeater will be due to the users on the other repeater. Of the 100 users, 5 will be off frequency in your direction, 5 will be over deviating, and 3 of those 5 will be unable to locate the deviation pot given a pictorial, schematic, detailed instructions and two helpers. Also, they are difficult to communicate with. They are users of the "other" system, and as users, they are not on all the time, or have unlisted phone numbers, etc. It was the realization of these two facts that conceived the reverse splits:

a. There will be interference
b. It will come from users

Remember, USER is a four letter word.

Now, consider if the adjacent channel interference came from another repeater. How nice it is. You have *one* guy to worry about, also capable of the best equipment, and he is of the same "cut" as yourself. You know him and can work with him to minimize your interference. Remember that you are probably interfering with him as much as he is interfering with you. The one-on-one situation provides a much more constructive atmosphere for solving problems, and there is always the local coordinating group you both can appeal to for mediation. This is the basis for reversing the split channels.

To implement this concept, the inbetween "15-kHz" channels are reversed (input and output) from the "30-kHz" channels. This will place the input for a "15-kHz" repeater adjacent to the output of a "30-kHz" repeater and vice versa.

Such a nice thing. But it is not without problems. First, but not the most important, is that the users of one system are interfering with users of the other system. A situation they are universally unequipped to handle. But their location is usually transient, and their range is considerable less than that of the repeater, and they should be more capable of tolerating interference. Remember, the "other" users are interfering with your users capability to hear your repeater. As most repeaters are verq strong, the average user will only rarely have damaging interference. Also, if it were not reversed, he would have to sort your repeater out of the "other" strong repeater output, not just some other user.

Another problem is intermod. The reverse concept actually causes somewhat more intermod in the repeater receiver due to the strong "other" repeater output. This is a theoretical problem in that we in SCRA have yet to experience such a problem. Again, the repeater is better equipped to cope with the problem. The user is in a considerably better intermod environment with his cheap radio, since he doesn't have a number of 15-kHz spaced mountains bearing down on him.

The worse problem with reverse splits is that the two (or more) interfering repeaters are both on high places. Boy, can they get into each other. But, this situation is controllable. The local frequency coordinating group can control the allocation to ensure adequate spacing (or other factors that effect space loss), to ensure the inevitable interference is workable. Although the SCRA has a reverse split working without interference at 18 miles spacing , from the adjacent channel the general rule is to keep the spacing up to 40-50 miles. (The 18-mile one has considerable natural barriers.) This gives the repeaters a chance at the problem.

Most important is that the SCRA does not recommend a complete conversion to reverse splits. There are situations where the reverse split is detrimental, and should not be applied. If there is only one high place around, it is ludicrous to place two systems on 15-kHz adjacent channels, reversed, and a mile apart. In this case, don't reverse the "15-kHz" channels. They must have breathing room. Out of this comes a general rule that should be applied on an individual basis:

a. If the repeaters are close together and/or if the users are separated, then *don't* reverse.

b. If the repeaters are far apart (over 50 miles) and the users are in a common area such that they can equally reach either repeater, then reverse is the way to go.

Hardware

The following hardware discussion is equally applicable to reverse splits or not, and is based upon experiences here in Southern California.

Transmitter

Besides the obvious factors of being on frequency, and reducing modulation below 5 kHz, there are several things that can be done to reduce your interference to your adjacent channel. Almost all transmitters have modulation limiters to limit the peak modulation voltage and control the deviation. These circuits should be set to only correct obvious overdeviation conditions, and not as an "average modulation" enhancer. They are not usually designed to work as speech compressors, and severe spectrum splatter can result. If you have the money, a CBS Volumax will perform a beautiful job on the average-to-peak ratio, without spreading garbage all over the place. Even with the limiters set to just catch the peak-peaks, the filter after the limiter should be changed. It is really this filter that rolls off the modulation above 3 kHz. Most imported radios have only 6-12 dB/octave, and even the majestic Motorola uses 15-18 dB/octave. It is recommended that this filter be increased to 24 dB/octave with a 3 dB point at 3 kHz. Be sure that the pre-emphasis and/or de-emphasis are correct. If all else (including receiver modification below) fails, then reduce deviation below 5-kHz. Most users can't tell 4 kHz from 5, but it sure makes a difference in the adjacent channel.

Keep your tones down. The MCW ID needs only to be 500-1000 Hz dev. It can be easily read. Remember, the ear can dig a tone out of 20 dB of noise, where voice can only be read at −5 dB SNR. If you're running autopatch or have touchtones, keep their level to 3.5 kHz deviation. The SCRA is presently preparing standards for tone levels that will not get into the next guy, but will still dial the phone; it's tight, but there is a way. Tone burst is archaic and should be replaced with sub-audible tones.

Antennas

Manipulation of antenna patterns to reduce interference is to be considered.

Receivers

Strangely, the most improvement is usually obtained by changing the receiver I-F filter. First, don't be shy about being too narrow. Remember that the effective I-F bandwidth grows wider as the signal gets stronger. Several repeaters here in L.A. are using Murata "G" filters which are only 8-kHz wide at 6 dB. They grow to 18 kHz at 70 dB (for receiver with 0.5 microvolt sensitivity, the filter will cross the magic 14-kHz point at about 10 microvolts). Weak signals had better be on channel, and will suffer from some distortion due to the bandwidth, but it works.

If you have a choice on the receiver, start with a converted VHF marine radio. The Motorola Metrum II, and some Pace models, fall in this catagory (or modify one yourself). These receivers were type-accepted for use on the 20-kHz spacing of the marine VHf band, and have considerably sharper filters than "2 meter" or hiband radios. Crystal I-F filters have some distortion of their own, but the KVG 12-kHz filter works well for single-conversion receivers. The use of RF crystal filters doesn't help the 15-kHz spaced adjacent channel problem but it sure does a job on intermod.

Conclusions

15-kHz spaced repeaters will work but not without effort. Stock receivers, transmitters and off-the-shelf repeaters usually are not adequate, and require modification. If a "split" is coordinated next to your Sensicon A-14OD repeater, you had better start looking for something better.

Obviously, 15-kHz tertiary channels are not easy to establish and maintain. The fact that amateurs have succeeded in this endeavor is somewhat amazing when you think of the other services which have stated that this was an impossibility. Are there other alternatives? Is 15-kHz the only way to go when there are no longer any available 30-kHz channels on two meters?

Some amateurs feel there is a better way. In the Pacific Northwest, a number of repeater councils have opted for a total reconstruction of the 2-meter amateur repeater sub-band from 146 to 148 MHz to make it follow the scheme utilized in the 144.5 to 145.5-MHz sub-band. One of those responsible for this move was Clay Freinwald, K7CR, of the Western Washington Repeater Association. Clay explains the thinking of the Pacific Northwest and the reasons they chose 20-kHz spacing over 15-kHz spacing.

20-KHZ CHANNEL SPACING FOR 2-METER FM

Clay Frienwald, K7CR

The Band Plan as Proposed:	The Band Plan as Existing:
Low In . . . High Out from 146 to 147	Low In . . . High Out from 146 to 147
High In . . . Low Out from 147 to 148	High In . . . Low Out from 147 to 148

The Band Plan as Proposed:	The Band Plan as Existing:
600kHz in/out spacing	600kHz in/out spacing
20 kHz Channel Spacing	30kHz Channel Spacing
Totals . . . 39 Repeater Pair 21 Simplex Channels	Totals . . . 27 Repeater Pairs 13 Simplex Channels
First Channel 146.02/62 Last Channel 147.98/38	First Channel 146.01/61 Last Channel 147.99/39
All Frequencies are even numbered	Frequencies are odd and even numbered
National Simplex Freq . . . 146.52	National Simplex Freq . . . 146.52

Repeater Pairs that would be effected.

All Odd Numbered Pairs . . . they would have the option of moving either up or down 10 kHz (up in the case of 01/61 and down in the case of 99/39) or in the case that this change would give an opportunity for councils to correct coordination mistakes of the past. Those cases might make it desirable for an existing operation to move to another, non-10 kHz adjacent frequency.

In short, All ODD numbered pairs would be given the opportunity to QSY 10 kHz to allow a new operation to come on.

Even Numbered Pairs . . . including the classic pairs of 04/64-16/76-22/82-28/88 and 34/94 and the popular simplex frequencies of .46, 52, and 58, would remain the same. This method displaces the minimum number of repeaters.

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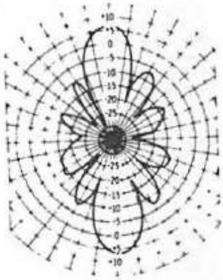

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